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ABSTRACT

The activities presented in this book are the product of the Community Outreach Initiative of the Microbial Literacy Collaborative (MLC). This activity book presents a balanced view of microbes, their benefits, and the diseases they cause. Each activity starts with an interesting introductory statement and includes goals, activity time, time to get ready, materials needed, getting ready, useful information, suggestions to modify the activity for those who are exceptional, more information, how to start the activity, making a hypothesis, what the data mean, and questions to think about, safety notes, what to do, and what was found out by doing the activity. Background information on the activities, general consideration for modification and assessment, and standard information are all included. The activities are divided into four categories: (1) "Tree of Life"; (2) "Keepers of the Biosphere"; (3) "Dangerous Friends and Friendly Enemies"; and (4) "Creators of the Future". (YDS)

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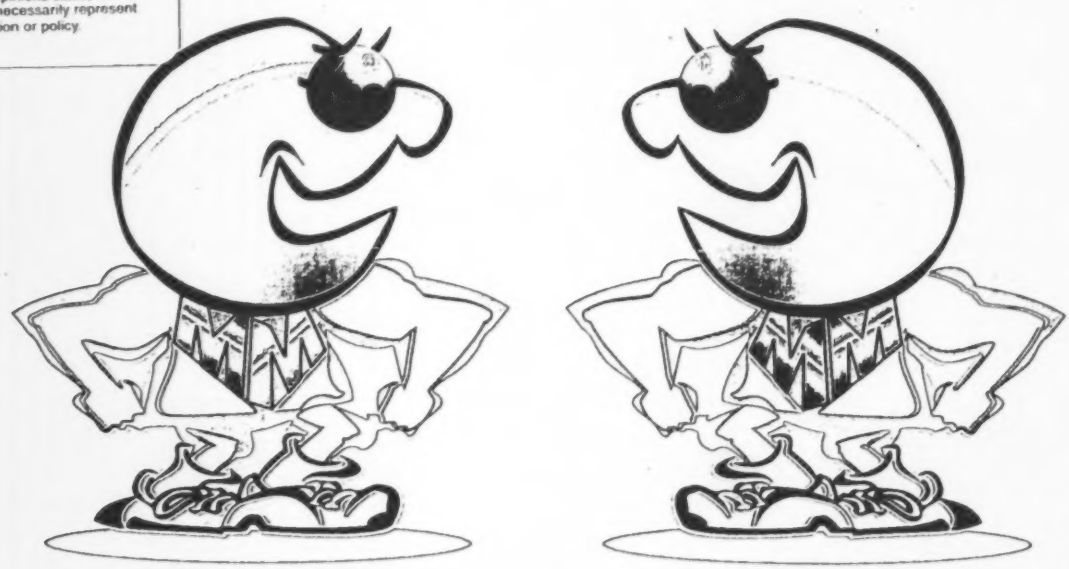
MEET THE MICROBES through the MICROBE WORLD ACTIVITIES with



MICROBE THE MAGNIFICENT

MIGHTY MICROBE

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The safety procedures included with each activity were written to assist facilitators in conducting the *MicrobeWorld Activities* with participants from their community. While every effort has been made to anticipate questions and situations that could arise, the safe implementation of these activities must depend on the good judgment of the facilitators and is the responsibility of the local institution. We suggest that facilitators consult state or local safety manuals or textbooks for additional information.

NABT recognizes the pervasive social phenomenon of litigation with respect to even the most unfounded claims. For that reason, NABT disclaims any legal liability for claims arising from use of these activities. This information has been provided to facilitators and institutions as a service to the profession and we provide this material only on the basis that NABT has no liability with respect to its use. Responsibility for use of any of this information is assumed by the local institution.

NABT believes that under the guidance of a properly trained and responsible facilitator all of the *MicrobeWorld Activities* can be conducted safely.

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Welcome to the MICROBEWORLD ACTIVITIES

Background of the development of the *MicrobeWorld Activities*

The *MicrobeWorld Activities* is the product of the Community Outreach Initiative of the Microbial Literacy Collaborative (MLC) and was made possible by generous funding provided by the National Science Foundation with additional funding by the Department of Energy and The Foundation for Microbiology. The MLC is an initiative of the American Society for Microbiology (ASM) to educate the public about the positive aspects of microbes and has three initiatives: Community Outreach, Public Outreach, and Education. The Community Outreach Initiative is related directly to the Public Outreach Initiative which is the four-part video series *Intimate Strangers: Unseen Life on Earth* produced by Baker & Simon Associates in association with Oregon Public Broadcasting. The series focuses on both the positive and negative aspects of microbes and addresses four major areas-evolution, environment, disease, and biotechnology. These issues are further explored in the Education Initiative's distance learning course and textbook and ancillary materials developed for undergraduate education.

The goal of the MLC is to present a more balanced view of microbes, educating the public about their positive aspects as well as their role in disease. The deadly and frightening aspects of microbes have been highly publicized, but the crucial role they play in our daily lives has not been emphasized, especially with the general public. The *MicrobeWorld Activities* complements the four-part video series *Intimate Strangers: Unseen Life on Earth* and is designed so that a science background is not required to implement the activities. All the activities have been field-tested nationally in diverse community outreach audiences, such as church groups, PTO's, Boy and Girl Scouts, 4-H groups, and science and museum centers. The activities have been welcomed for their simplicity, ease of understanding and implementation, and their low-cost, easily found equipment and materials. The use of familiar items from dollar and grocery stores adds to the user-friendly aspect of the activities. The activities are written at the sixth to eighth grade level, but they are easily modified for audiences of all ages.

In addition to developing, writing, and publishing the *MicrobeWorld Activities*, the National Association of Biology Teachers (NABT) has conducted three summer youth leadership training institutes. These institutes provided training and additional background to youth for implementing the activities in their home communities. In the summer of 1998, NABT partnered with ASM and the Association for Science-Technology Centers Incorporated, the Science Museum of Minnesota, and the University of Minnesota, St. Paul to conduct a national training institute for youth from science and museum centers nationwide. In 1999, NABT partnered with ASM and the American Association for the Advancement of Science and The George Washington University to conduct a national and a local institute in Washington, DC. The 37 teams of youth leaders and their adult sponsors from these institutes have implemented the activities in their home communities with groups, such as 4-H, Boy and Girl Scouts, Boys and Girls Clubs, church groups, PTO's, and science and museum centers.

How the *MicrobeWorld Activities* are set up

Each activity begins with an introductory statement to pique interest and is divided into facilitator and participant pages. The **Facilitator Page** is intended for use by the person presenting the activity. The participant page is intended to be copied and distributed to the participants to use as a guide while doing the activity. The **Facilitator Page** has the following sections:

- **Goal** describes the expected participant outcome.
- **Activity Time** indicates the approximate time to do the activity with participants.
- **Time to Get Ready** indicates the time needed to prepare materials for the activity.
- **What You Need** lists equipment and materials needed for each team of participants.
- **Getting Ready** provides information and tips to prepare to implement the activity.
- **Useful Information** provides easily understood background information about the concepts presented.
- **Suggestions to Modify the Activity for Those Who Are Exceptional** contains information about how to modify the activity for exceptional participants.
- **For More Information** identifies references and readings for further understanding of the information presented.
- **How to Start the Activity** provides suggested ways to introduce the activity to participants, such as demonstrations, discrepant events, and leading questions to stimulate participant interest.
- **Let's Make a Hypothesis** includes questions for discussion that guide the participants as they make hypotheses.
- **What the Data Mean** shows sample data and provides an explanation of the data.

The **Participant Page** has the following sections:

- **Questions to Think About** is an introductory paragraph to guide participants' thinking about the concepts presented in the activity.
- **Safety Notes** provides information and tips for conducting the activity safely.
- **What to Do** is a list of steps for setting up the activity followed by ways to design an investigation resulting from the activity.
- **What Did You Find Out By Doing the Activity?** allows participants to assess their understanding of the concepts before and after doing the activity.

In addition, participants and facilitators are encouraged to access the MLC web site *www.microbeworld.org* to share what they have learned while doing the activity and contact one of the MicrobeMentors with questions or ideas about the activities. The MicrobeWorld Mentors are the youth leaders who participated in the summer training institutes held at the University of Minnesota in St. Paul, MN and The George Washington University and the American Association for Advancement of Science in Washington, DC.

General considerations for modifying the *MicrobeWorld Activities* for those who are exceptional

In all community outreach efforts to educate the public about microbes, it is essential to accommodate all learning needs where possible. The *AAAS Barrier-Free in Brief* series is an excellent source of information on science/mathematics learning and disability. The four-booklet series is unique, succinct, and reliable. Some of these booklets have addresses of agencies that can provide information about obtaining assistive technology, such as Assistive Listening Devices (ALDs); light probes; and talking thermometers, calculators, and clocks. Anyone or all of the booklets are available FREE from AAAS; Project on Science, Technology, and Disability; 1333 H Street, NW; Washington, DC 20008; (202) 326-6630 (V/TDD); (202) 371-9849 (FAX); bgoodric@aaas.org (E-mail). The following are general modifications that may be used with all of the activities contained within the *MicrobeWorld Activities*. In addition, each activity contained within this guide provides activity-specific suggestions under the heading entitled **Suggestions to Modify the Activity for Those Who Are Exceptional.**

Blind or Visually Impaired

- Produce directions and handouts in large print or braille depending upon the individual participant's language needs. Participants may have access to a braillewriter or will be able to advise the facilitator what font size to use for large print. Eighteen point is recommended usually. Tape-recorded instructions will allow the participant to do the activity independently.
- Use small pieces of tape or dabs of glue to mark measurements on equipment, such as rulers, beakers, and graduated cylinders. This will benefit the participant who does not have access to a braillewriter.
- Place objects for each group in identical areas that are marked clearly with braille or large print. If marking the areas is not feasible, repeat the placement of station areas for each session. This will allow the facilitator to provide consistent, organized steps that will provide a better understanding of the activity's purpose.

• Use different grades of sandpaper, textured tape, and/or yarn to make raised images of diagrams discussed in the activity to emphasize the concept presented.
• Record data and observations on a tape recorder for development of graphs.
• Use available technology to develop graphs. The graphs may be made with materials such as pegs and pegboard for a line graph or with educational counters called cubed manipulatives for a bar graph. Input from group discussions may be transcribed into braille by using a Swail Dot Inverter or done in large print on a computer with voice output.

Deaf or Hard-of-Hearing

• Discuss language requirements and the language of new concepts with participants. This is also a good time for the interpreter to develop appropriate signs for the new concepts that are introduced to the participant. Although an independent choice, sitting in the front of any discussion area would be beneficial for individuals who depend on lip reading or use a sign language interpreter.
• Emphasize any visuals or hands-on aspects of the activity.
• Keep diagrams that relate to the activity visible at all times to allow for easy reference to any orally missed concepts.

Mobility Impaired

• Note all the areas where the activity requires group meetings to make certain that there is adequate space at and around the activity area. The circulation route to and from the activity should be no less than 1 meter (36 inches) wide. The turn around space should have a diameter of 1.6 meters (60 inches).
• Provide easy access to all materials and equipment at all workstations. Objects should be within arm's length. If objects are in cupboards and not accessible, collect and prepare the supplies before the activity.
• Provide the participant with a knee space that is 0.7 meters (27 inches) high, 0.8 meters (30 inches) wide, and 0.5 meters (19 inches) deep. The work surface should be 0.75 to 0.9 meters (28 to 34 inches) above the floor.
• Provide an observation area with adequate seating and at a height of 1 meter (36 inches) for comfortable and accessible viewing.

Physically Impaired

• Ask the participant to describe his abilities before the activity to provide an understanding of what can be done independently and without adaptations.
• Use beans for counting. Their larger size is easier to count and manipulate.
• Adapt measuring instruments for gross and fine motor skills, as necessary. If instruments with handles make it difficult to transfer the liquid or soil, locate an equivalent without a handle. Wrapping an elastic band around the measuring device will give the participant a better grasp. Communicate with the participant regarding the best way to adapt equipment.
• Provide an observation area that has adequate seating with a height of 1 meter (36 inches) for comfortable and accessible viewing.
• Provide loop-handled scissors for individuals with low hand dexterity. The scissors have a loop that allows for an easier grip instead of finger rings found on regular scissors and have "stoppers" that prevent the hand from slipping onto the blade. They are readily available at any school supply store.

Cognitively Impaired

• Communicate with all team members involved.
• Accommodate the five senses.

How the *MicrobeWorld Activities* relate to the *Intimate Strangers* video series

The *MicrobeWorld Activities* complement the *Intimate Strangers* video series. The following chart shows the relationship between the series content and the goals of the *MicrobeWorld Activities*.

Intimate Strangers: Unseen Life on Earth	*MicrobeWorld Activities*
Program One: The Tree of Life As scientists map the human genome, they find the ancient DNA of microbes at the roots of our family tree. This hour follows the quest of scientists to understand how all life on the planet is related. 	**Creepy Critters** To develop a classification scheme based on the structural features of organisms and then use the scheme to classify newly discovered organisms. **Forever and a Day** To introduce geological history and a few of the major events that occurred during the Earth's 5 billion years. **Mega Multiples of Microbes** To visualize large numbers and calculate microbial population growth. **Natural Selection** To demonstrate that natural selection results in populations different from the original.
Program Two: Keepers of the Biosphere Microbes drive the chemistry of life. They affect the global climate. They do most of the recycling that keeps the world habitable. This hour follows scientists who are exploring our reliance on this invisible world. 	**Biosphere in a Bottle** To investigate microbes that exist in a column of mud and the role of light in their survival. **Bread Box Nightmares** To investigate the factors needed for fungi to grow and develop. **Can Microbes Tell the Difference?** To compare the energy content of various sweeteners by measuring yeast's production of carbon dioxide when using sweeteners as food. **Nature's Trash Compactors** To observe microorganisms and macroorganisms that contribute to decomposition and determine factors important in decomposition. **Now You See It, Now You Don't** To investigate the process by which commercial packing peanuts biodegrade.
Program Three: Dangerous Friends and Friendly Enemies Infectious diseases occur when our relationship with microbes changes or when an intruder invades. This hour follows scientists who seek to understand our most personal relationships with this invisible world. 	**Caught Red-Handed** To evaluate the effectiveness of different handwashing times, techniques, and materials in reducing the number of microbes. **Defend Your Surface** To design and test a surface that prevents harmless microbes from sticking to it. **Let's Get Small** To develop an understanding of the comparative sizes of microbial life, including viruses, protozoa, bacteria, and very small parts of the human body. **The Yeast of Our Worries** To investigate strategies for reducing microbial growth.
Program Four: Creators of the Future The 21st century challenges us to reclaim our damaged environment and feed a growing population. This hour introduces scientists who are turning to microbes for solutions. 	**Cabbage Today, Sauerkraut Soon** To demonstrate how bacteria naturally present on cabbage can change it into the common, fermented food sauerkraut. **Fun with Fomites** To investigate strategies for reducing bacteria on object surfaces. **Puddles** To discover the abundance and diversity of microbial communities in puddles. **Yeast on the Rise** To investigate variables that affect the energy and carbon dioxide production of yeast in bread dough.

How the *MicrobeWorld Activities* address assessment and standards

Today, accountability is a function of informal, as well as formal education. Assessment of what is learned and standards for that learning provide accountability for the processes and content of each learning environment. The *MicrobeWorld Activities* seek to educate the public on what a microbe is and the importance of microbes in our daily lives. In addition, the activities seek to involve the community outreach participants in what an experiment is, how to design an experiment, and how to ask good questions. Each activity has a section entitled **What Did You Find Out By Doing the Activity?** This section contains an activity-specific checklist that assesses the participant's understanding of the activity. Each checklist contains questions about what the participant understood about microbes before and after doing the activity. The questions relate to not only the content, but also to what and how information was discovered in the activity and how that information is relevant and applicable to daily life. Two general questions that may be used for assessment for each activity are:
1. Was the activity easy to do and understand?
2. Did your awareness of microorganisms increase as a result of doing this activity?

The activities have been aligned with the *National Science Education Standards* (*NSES*) developed by the National Research Council and *New Standards™ Student Performance Standards* developed by the National Center on Education and the Economy. Each set of standards has been placed in a matrix. A check mark indicates which activity is aligned with which standard of each document.

National Science Educational Standards	Biosphere in a Bottle	Breadbox Nightmares	Cabbage Today, Sauerkraut Soon	Can Microbes Tell the Difference?	Caught Red-Handed	Creepy Critters	Defend Your Surface	Forever and a Day	Fun with Fomites	Let's Get Small	Mega-Multiples of Microbes	Natural Selection	Nature's Trash Compactors	Now You See It, Now You Don't	Puddles	The Yeast of Our Worries	Yeast on the Rise
Unifying Concepts and Processes																	
Systems, order, and organization	x	x				x				x		x	x				
Evidence, models, and explanation	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Change, constancy, and measurement	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Evolution and equilibrium	x					x	x	x				x	x		x		
Form and function	x	x	x			x	x		x					x	x		x
Science as Inquiry																	
Abilities necessary to do scientific inquiry	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Understanding about scientific inquiry	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
History and Nature of Science																	
Science as a human endeavor	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
Nature of science	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
History of science						x		x									
Physical Science																	
Properties and changes of properties in matter	x	x	x	x			x		x				x	x	x	x	x
Transfer of energy	x	x	x	x									x	x	x	x	x
Life Science																	
Structure and function in living systems	x	x	x	x			x		x	x					x	x	x
Reproduction and heredity	x								x			x				x	x
Regulation and behavior	x								x			x	x				
Populations and ecosystems	x	x	x		x	x	x		x		x	x	x		x		
Diversity and adaptations of organisms	x				x	x	x	x	x	x		x			x		
Earth and Space Science																	
Structure of the Earth system	x							x					x		x		
Earth in the solar system	x																
Earth's history								x									
Science and Technology																	
Understanding about science and technology														x			
Science in Personal and Social Perspectives																	
Personal health		x	x		x		x		x	x						x	
Populations, resources, and environments	x	x					x					x	x	x	x		x
Natural hazards					x		x		x	x							
Risks and benefits							x			x						x	

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New Standards™ Student Performance Standards	Biosphere in a Bottle	Breadbox Nightmares	Cabbage Today, Sauerkraut Soon	Can Microbes Tell the Difference?	Caught Red-Handed	Creepy Critters	Defend Your Surface	Forever and a Day	Fun with Fomites	Let's Get Small	Mega Multiples of Microbes	Natural Selection	Nature's Trash Compactors	Now You See It, Now You Don't	Puddles	The Yeast of Our Worries	Yeast on the Rise
Life Science Concepts																	
Demonstrates conceptual understanding by using concepts to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding explaining and representing are required to meet this standard.																	
Structure and function in living systems, such as the complementary nature of structure and function in cells, organs, tissues, organ systems, whole organisms, and ecosystems.	X	X	X	X			X		X								
Reproduction and heredity, such as sexual and asexual reproduction; and the role of genes and environment on trait expression.	X		X	X										X	X		X
Regulation and behavior, such as senses and behavior; and response to environmental stimuli.	X												X				
Populations and ecosystems, such as the roles of producers, consumers, and decomposers in a food web; and the effects of resources and energy transfer on populations.	X	X	X	X								X	X		X	X	X
Evolution, diversity, and adaptation of organisms, such as common ancestry, speciation, adaptation variation, and extinction.						X		X				X					
Earth and Space Sciences Concepts																	
Demonstrates conceptual understanding by using a concept to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts as appropriate). Both aspects of understanding explaining and representing are required to meet this standard.																	
Structure of the Earth system, such as crustal plate and land form; water and rock cycles, oceans, weather, and climate.	X							X									
Earth's history, such as Earth processes including erosion and movement of plates, change over time, and fossil evidence.								X				X			X		
Scientific Connections and Applications															X		
Demonstrates conceptual understanding by using a concept to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding explaining and representing are required to meet this standard.						G											
Big ideas and unifying concepts, such as order and organization; models, form, and function; change and constancy; and cause and effect.	X					X	X	X	X	X	X	X	X		X		
Impact of science, such as historical and contemporary contributions; and interaction between science and society.	X													X			
Scientific Thinking																	
Demonstrates scientific inquiry and problem solving by using thoughtful questioning and reasoning strategies, common sense, and conceptual understanding from Science Standards 1 to 4, and appropriate methods to investigate the natural world.																	
Frames questions to distinguish cause and effect; identifies or controls variable in experimental and non-experimental research settings.		X		X			X		X					X	X	X	X
Uses concepts to explain a variety of observations and phenomena.	X	X	X	X	X		X	X	X	X	X	X	X	X	X	X	X
Uses evidence from reliable sources to develop descriptions, explanations, and models.	X				X	X		X		X	X	X			X	X	X
Proposes, recognizes, analyzes, considers, and critiques alternative explanations; and distinguishes between fact and opinion.	X	X		X	X						X			X	X		
Identifies a problem; proposes and implements solutions; and evaluates the accuracy, design, and outcomes of investigations.		X	X	X	X		X							X	X	X	X
Works individually and in teams to collect and share information and ideas.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Scientific Tools and Technologies																	
Demonstrates competence with the tools and technologies of science by using them to collect data, make observations, analyze results, and accomplish tasks effectively.																	
Uses technology and tools(such as traditional laboratory equipment, video and computer aids) to observe and measure objects, organisms, and phenomena, directly, indirectly, and remotely.			X	X			X		X				X	X	X	X	X
Acquires information from multiple sources, such as experimentation, print, the Internet, and computer data bases.	X	X	X	X	X		X		X				X	X	X	X	X
Scientific Communication																	
Demonstrates effective scientific communication by clearly describing aspects of the natural world using accurate data, graphs, or other appropriate media to convey depth of conceptual understanding in science.																	
Represents data and results in multiple ways, such as numbers, tables, and graphs; drawings, diagrams, and artwork; and technical and creative writing.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Argues from evidence, such as data produced through his or her own experiments or those done by others.	X	X	X	X	X	X	X		X	X	X	X	X	X	X	X	X
Critiques published materials.	X				X		X	X	X								
Explains a scientific concept or procedure to other participants.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Communicates in a form suited to the purpose and the audience, such as writing instructions that others can follow; critiquing written and oral explanations; and using data to resolve disagreements.	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Scientific Investigations																	
Demonstrates scientific competence by completing projects drawn from the following kinds of investigations:																	
Controlled experiment		X		X	X		X		X					X	X	X	X
Fieldwork	X						X						X		X		
Design	X	X	X	X	X		X	X				X		X	X	X	X
Secondary research, such as use of others' data	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Non-experimental research using print and electronic information, such as	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X

CREEPY CRITTERS

What if you discovered a completely new life form? Would you be able to determine what existing organisms it might be related to? What would you look for? How would you organize your research?

Goal

To develop a classification scheme based on the structural features of organisms and then use the scheme to classify newly-discovered organisms.

Activity Time

60 minutes

Time to Get Ready

15 minutes

What You Need

Have the following for each team of 4:

1 set of Organism Cards

1 piece of paper

1 pencil

1 pair of scissors (optional)

1 set of Newly Discovered Organism Cards

Getting Ready

- Make 1 set each of Organism Cards and Newly Discovered Organism Cards for each group of 4 participants. See Figures 1 and 2 on pages 2 through 4. If each group has a different color, it will be easier to keep them organized. You may cut and bundle the cards for each group ahead of time or have the groups do it before the activity.
- Become familiar with common examples of classification systems such as sorting items in a market, the postal system, educational levels, and libraries.
- Be aware that there is more than one way to design a classification system, and different sorting criteria may be used. Be prepared to accept any classification scheme that can be justified by the group.

Useful Information

Scientists have organized living things into large groups called kingdoms based on natural relationships. Early classification systems were based only on structural similarities. Today, we consider similarities in cell make-up, genetics, and more when classifying organisms. Plants make up one kingdom, and animals another. Protists, bacteria, and fungi make up still more kingdoms. Things are placed into a kingdom based on their similarities. The kingdoms are then divided into smaller and smaller groups. The more similar living things within a kingdom, the more closely they are grouped. The smallest group within a kingdom is a species. Members of different species cannot interbreed. This whole organizational system for living things is called "classification."

It works like this. Suppose you wanted to classify a car. See Figure 3.

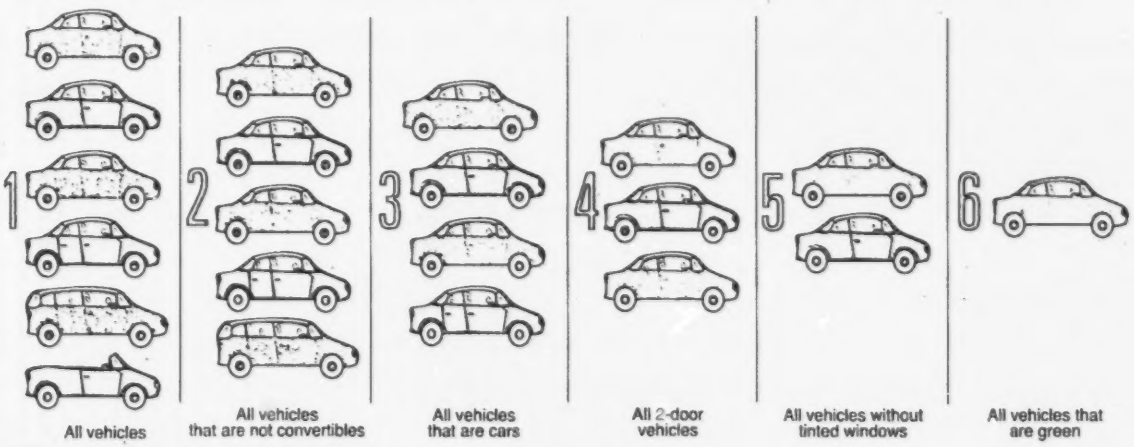

Figure 3. One way to classify cars.

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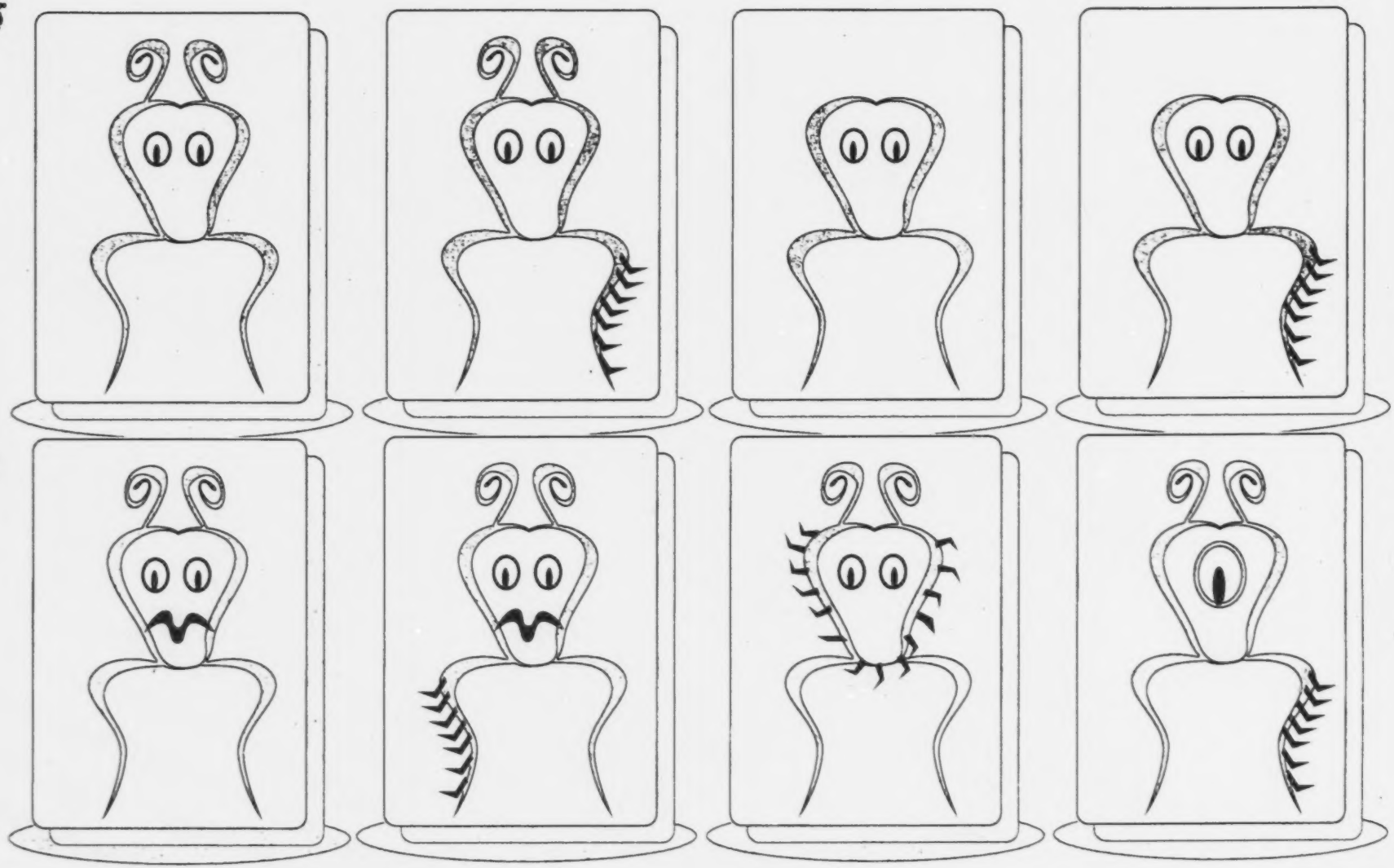
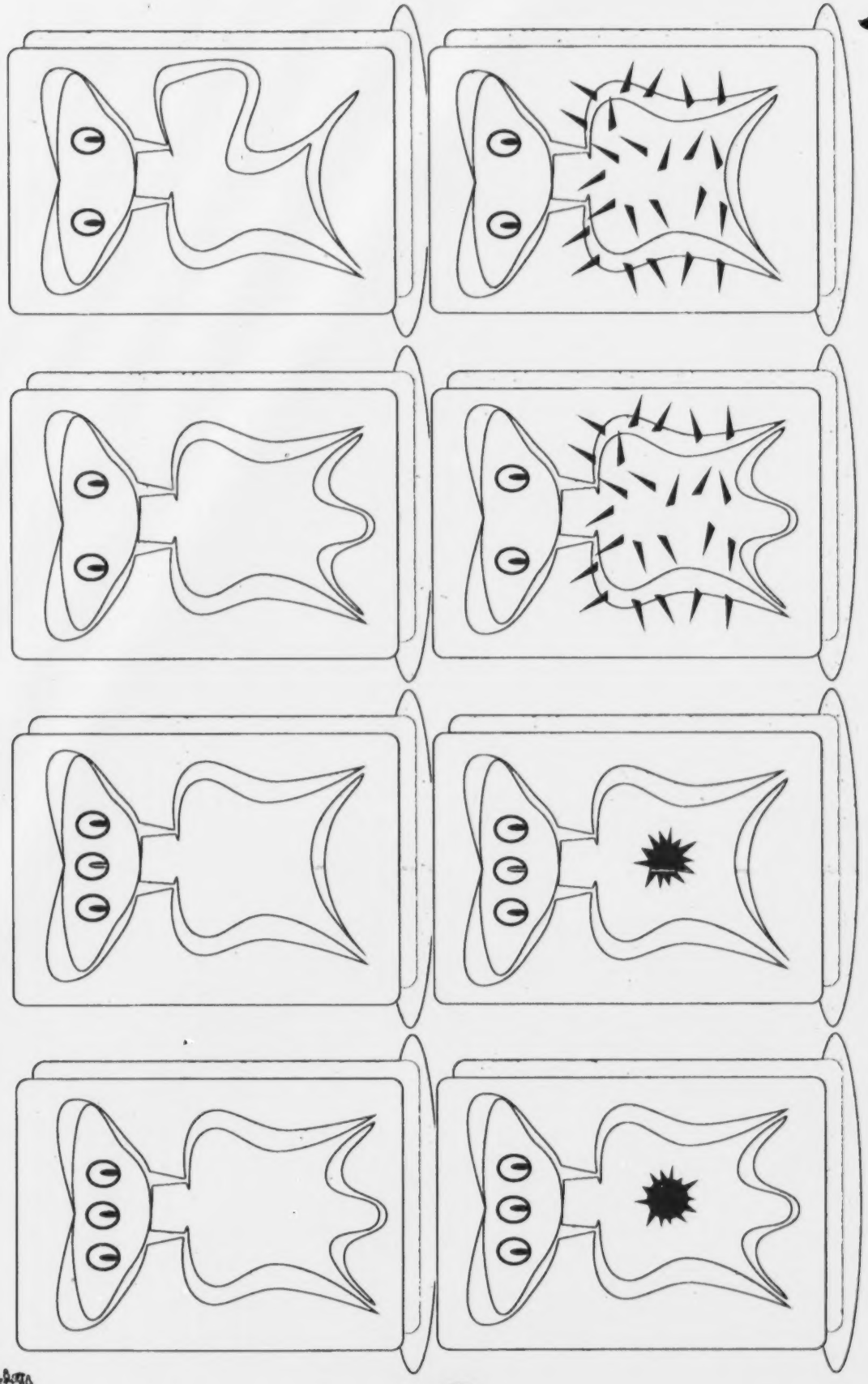
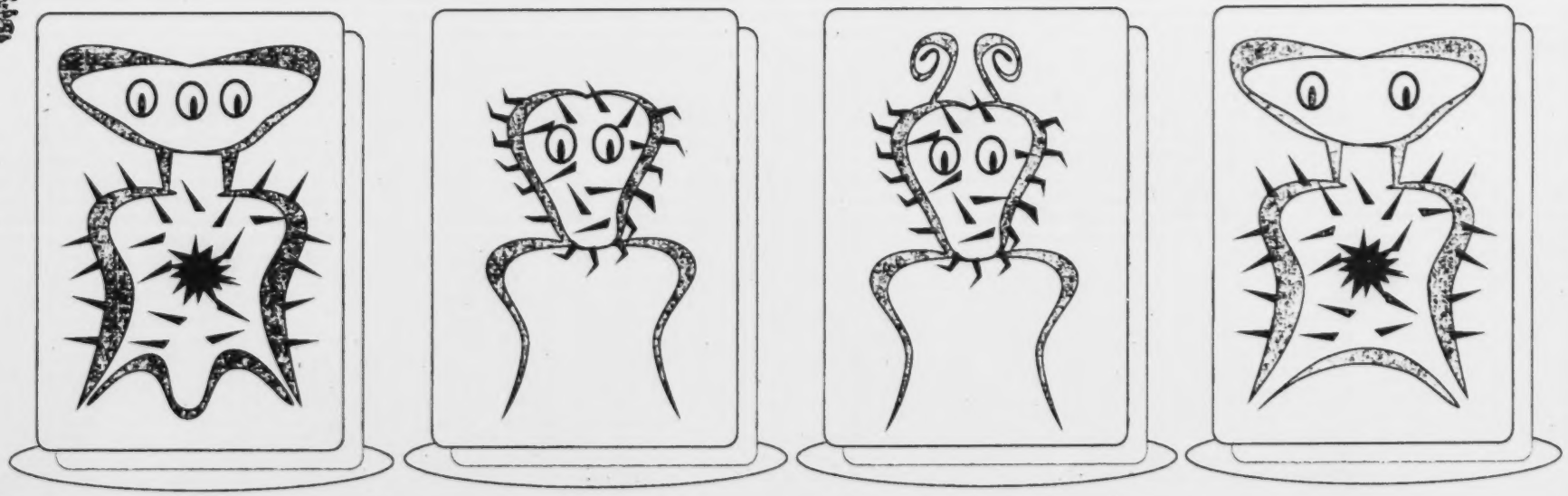


Figure 1. Organism Cards.
The 20 cards are found on pages 2, 3, and the top row of page 4.





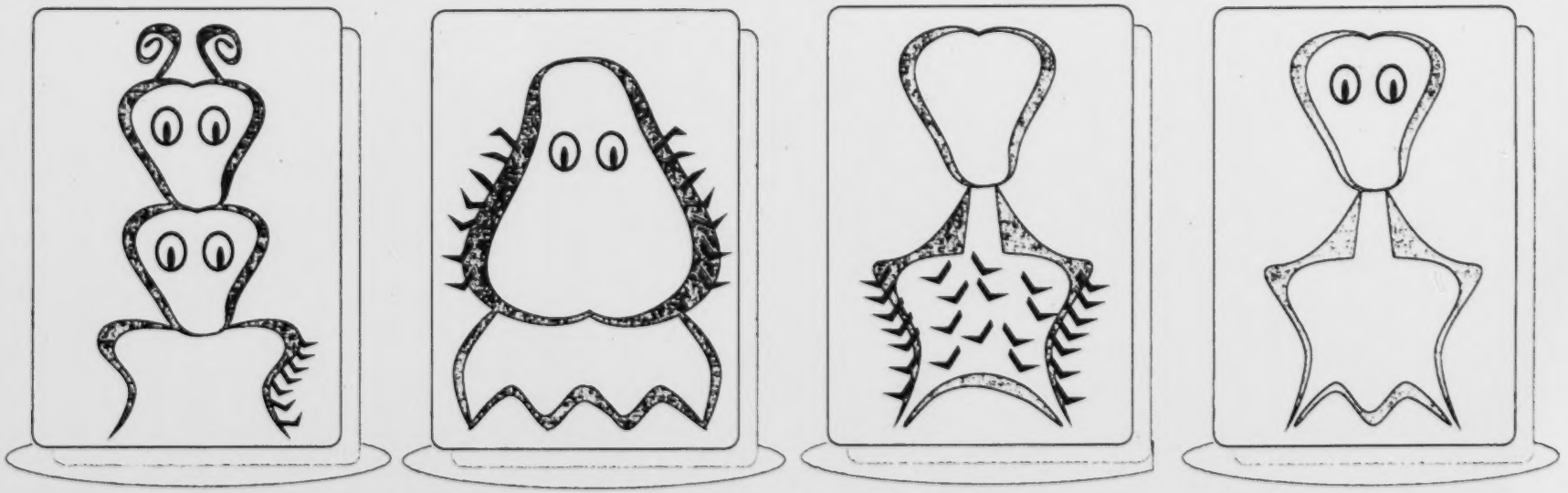


Figure 2. Newly Discovered Organism Cards.
Only cut the 4 cards in the lower row.

The first group, or kingdom, would be all cars. That would exclude trucks, school buses, and RVs. The kingdom of cars would be further divided into all sedans. Now we've excluded all convertibles and station wagons. The third group would be all 2-door sedans. That eliminates all the 4-door models. The fourth group would be all 2-door sedans with tinted windows. The fifth group would be all 2-door sedans with tinted windows and stick shifts. The sixth group would be all green, 2-door sedans with tinted windows and stick shifts. And the last group would be all green, 2-door sedans with tinted windows, stick shifts, and CD players. Each group contains fewer cars than the one before because additional requirements were added. Classification of living organisms works the same way. Each group within a kingdom has fewer members than the group before. See Figure 3 for a simple car classification scheme.

Many times, different scientists classify organisms differently. For example, another scientist might classify the car in the example above like this. The first group would be all cars. The second group would be all cars made in the United States. The third group would be all cars made by General Motors. The fourth group would be all Pontiacs. The fifth group would be all sports cars. The sixth group would be all convertible sports cars. And the last group would be all convertible Trans Ams. Again, each group contained fewer cars than the one before as the system went from general to more specific.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Enlarge the Organism Cards with a copy machine or produce them in braille.
- Use height as an alternative method for introducing classification. The same rules can apply, but this adaptation will allow for the participant to interact independently by using his/her sense of touch.
- Have the participants classify desk items or publications. Encourage them to repeat the exercise if necessary.
- Discuss each organism in detail as a group. Have the group provide many references to color, texture, and size. Repeat descriptions often. Individuals who are blind have a good understanding of color and size and will want the detailed observations to participate fully.

Deaf or Hard-of-Hearing

- Provide a pyramid chart that shows the breakdown of classification. Visuals are extremely beneficial for this activity.

Mobility Impaired

- Tape the Organism Cards on a blackboard or wall if they are not visible when grouped on the table.

Physically Impaired

- See the ***General Modifications*** for *Physically Impaired* listed in the **Introduction**, page V.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

For More Information

Angier, N. (1998). When evolution creates the same design again and again. *The New York Times, CXLVIII*(51,372).

Crisci, J.V., McInerney, J.D. & McWethy, P.J. (1993). *Order and Diversity in the Living World: Teaching Taxonomy & Systematics in Schools.* The Commission for Biological Education of the International Union of Biological Sciences in cooperation with UNESCO.

Green, K. (1993). Developing a cannamacule key. *Favorite Labs from Outstanding Teachers, Volume II.* Reston, VA: NABT Publications, 14-16.

Kessler, J.H. (Ed.). (1996). Classification. *WonderScience, II*(1).

Margulis, L. & Sagan, D. (1997). *Microcosmos: Four Billion Years of Evolution from Our Microbial Ancestors.* Berkeley, CA: University of California Press.

McComas, W. (Ed.). (1994). *Investigating Evolutionary Biology in the Laboratory.* Reston, VA: NABT Publications.

Reimink, R.L. (1995). Teach biodiversity at the bell. *The American Biology Teacher, 57*(2), 106-107.

Ross, C. (1993). Classification concentration. *Favorite Labs from Outstanding Teachers, Volume II.* Reston, VA: NABT Publications, 17-23.

Vogt, K.D. (1995). Demonstrating biological classification using a simulation of natural taxa. *The American Biology Teacher, 57*(5), 282-283.

How to Start the Activity

- Classification systems are based on structural similarities. Encourage the participants to discriminate among physical features of the samples provided.
- Have the participants line up in order by their birthdays. They may communicate only through hand and body motions. Talking and writing are not permitted while they organize the line. After they line up, confirm the birth dates of each participant to determine the degree of accuracy. Discuss the strategy used to sort everyone, and if alternate methods might have been used.

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- What are examples of items that are classified?
- Why are things classified?
- Is there more than one way to classify a set of items?

What the Data Mean

The results will vary with each classification scheme used.

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CREEPY CRITTERS

Questions to Think About

If someone from China sends you a letter, how does the postal system know where you are? How are supermarkets organized? If you go to a new supermarket, how would you know where to find a specific brand of cheese?

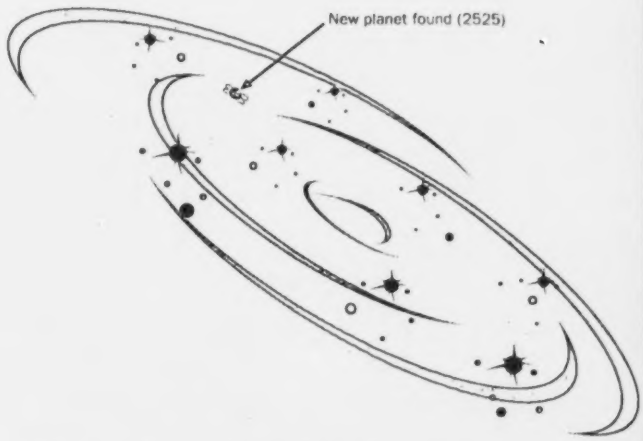
Imagine that in the year 2525, a solar system in a new galaxy is discovered. Many similarities between our solar system and this new one are found, including a planet that resembles Earth. A space probe lands on this planet and sends a variety of different living organisms back to Earth through a molecular transport beam. The macroscopic and microscopic structures of each creature are described. The scientists studying these organisms realize they need to develop a classification scheme to help them compare the life forms to organisms on Earth. Your role is to study the illustrations of the creatures and develop a possible classification scheme based on the information provided for each organism. You must be able to justify and defend the method that you use.

Safety Notes

- Exercise care when using scissors. Point them away from the body when cutting.
- Do not point scissors at other individuals.

What to Do

1. Study the Organism Cards carefully. Note feature similarities and differences of the creatures. Construct a table to help organize your observations. Columns to describe things like hair, antennae, and necks will be helpful.
2. Study the cards again and place them in groups based on the similarities and differences observed. Once the group is satisfied with the results, construct another table listing the characteristics common to each group.
3. Get a set of Newly Discovered Organism Cards from your facilitator. Select one of these organisms and suppose that it was just discovered. Where does it fit in your system of organization? Will you have to create a new group or can you find another way to fit it into an existing group?
4. Present your classification scheme to the large group. Make sure you can justify your methods. How does your classification scheme compare to those created by other groups?



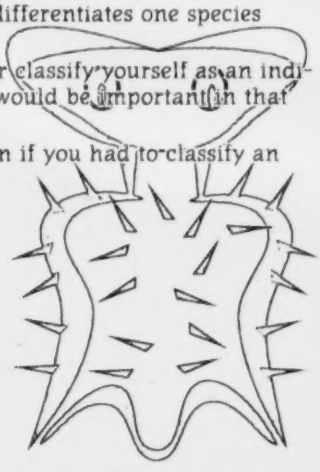
What Did You Find Out By Doing the Activity?

Before doing "Creepy Critters," did you know:

- that not all animals have the same characteristics?
- what the standard classification scheme for organisms is?
- how animals are separated into different groups?
- if how an animal looks has an effect on how it is classified?
- why scientists classify organisms?
- that the basic food groups are another form of classification?

From this activity, did you discover:

- how organisms are classified?
- what factors are most important in classification?
- what benefits come from classifying organisms?
- the major factor that differentiates one species from another?
- how you would further classify yourself as an individual, and what traits would be important in that classification?
- where you would begin if you had to classify an unknown plant?



FOREVER AND A DAY

We've all dreamed of winning a lottery. A $5 billion one would be great! What would all that money look like? How long would it take to spend it? Can you imagine 5 billion years of time on Earth? What could happen in all that time?

Goal

To introduce geological history and a few of the major events that occurred during the Earth's 5 billion years.

Activity Time

90 minutes

Time to Get Ready

15 minutes

What You Need

Have the following for each team of 4:

4 3-foot lengths of cash register tape

1 12-foot length of cash register tape

1 roll of cellophane tape

1 set waterproof, colored markers

4 rulers

14 note cards

Getting Ready

- Cut 1 3-foot length of cash register tape for each participant.
- Cut 1 12-foot length of cash register tape for each group of 4.
- If cash register tape is not available, tape sheets of paper together to make the desired lengths.

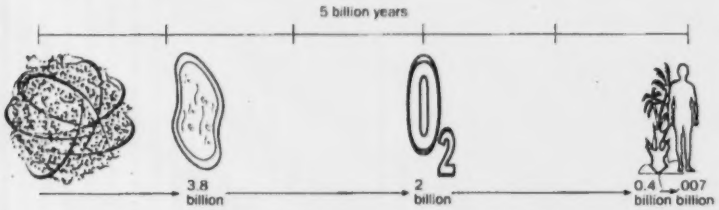


Figure 1. Simplified time line of the Earth.

Useful Information

The Earth has a long and eventful history. Scientists believe it was formed nearly 5 billion years ago. They know this date due to a process called radioactive decay. Naturally occurring radioactive materials break down into other materials at a known rate. The presence of various elements can be used to find the ages of rock formations.

A lot has happened in that 5 billion years. Understanding geological time and when things happened during that time is hard for most people. The numbers are just too large. Sometimes, it helps to place events in the order in which they happened. A time line is very useful for this. Some of the key events of the history of the Earth are shown in the following table. They can be used to help participants understand the concept of Earth's 5 billion years.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Refer to the number of zeros in the year when discussing the "Time and Event" section in **Useful Information** to provide the participant with a better understanding of how large the number is.
- Divide and mark the sections on both time lines with pieces of yarn to enable the participant to understand the concept of time and the placement of events.

- Construct tactile diagrams of the Earth's time line when writing out the note cards for the events to provide the participant with a visual of the time line. Suggested materials may be found in the ***General Modifications*** section found in the **Introduction** on page V.
- Emphasize group discussion of the comparison between the time line of the history of the Earth and the life history of the participant.

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- See the ***General Modifications*** for *Physically Impaired* listed in the **Introduction**, page V.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

Time Years ago	Billions of years ago (bya)	Event
4,600,000,000	4.6	Origin of the Earth
3,800,000,000	3.8	First cells (no nucleus) appear
3,700,000,000	3.7	Period of no free oxygen
2,200,000,000	2.2	Cyanobacteria (no nucleus) produce oxygen (a poison)
2,000,000,000	2.0	Oxygen accumulates in the atmosphere; cells evolve to use it
1,400,000,000	1.4	Complex cells (with a nucleus) appear
1,000,000,000	1.0	Advanced, more complex cells (with a nucleus) appear
700,000,000	0.7	Multicellular plants and animals appear
600,000,000	0.6	Marine invertebrates abundant
500,000,000	0.5	Earliest fish appear
380,000,000	0.380	Oxygen attains 20% level (current level)
360,000,000	0.360	First amphibians appear
350,000,000	0.350	Trees appear
300,000,000	0.300	First reptiles appear
235,000,000	0.235	First dinosaurs appear
220,000,000	0.220	First mammals appear
40,000,000	0.040	Flowering plants appear
65,000,000	0.065	Extinction of dinosaurs, birds appear
3,000,000	0.003	Human-like forms appear
50,000	0.00005	*Homo sapiens* (humans) appear

Table 1. Key events in the history of the Earth.

For More Information

Barker, N. & Foster, G. (1998). Ancient microworlds. *The Johns Hopkins Magazine, 50*(2), 18-23.

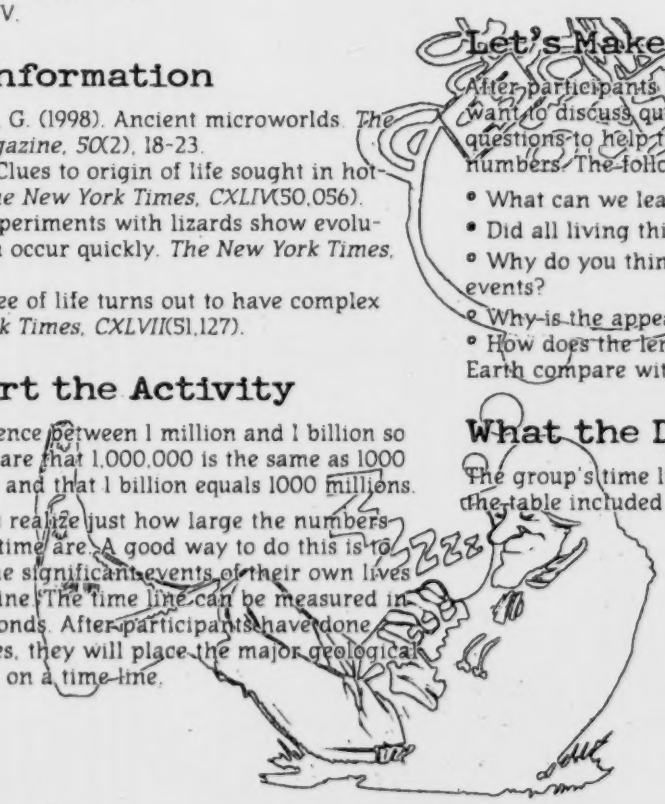
Broad, W.J. (1995). Clues to origin of life sought in hothouse microbes. *The New York Times, CXLIV*(50,056).

Wade, N. (1997). Experiments with lizards show evolutionary change can occur quickly. *The New York Times, CXLVI*(50,779).

Wade, N. (1998). Tree of life turns out to have complex roots. *The New York Times, CXLVII*(51,127).

How to Start the Activity

- Review the difference between 1 million and 1 billion so participants are aware that 1,000,000 is the same as 1000 multiplied by 1000; and that 1 billion equals 1000 millions.
- Help participants realize just how large the numbers used in geological time are. A good way to do this is to have them place the significant events of their own lives on a human time line. The time line can be measured in both years and seconds. After participants have done their own time lines, they will place the major geological events of the Earth on a time line.



Let's Make a Hypothesis

After participants have made their time lines, you may want to discuss questions that lead them to ask more questions to help them understand the concept of large numbers. The following questions are only suggestions.

- What can we learn from a time line?
- Did all living things appear on Earth at the same time?
- Why do you think so much time separates the major events?
- Why is the appearance of oxygen so important?
- How does the length of time living ferns have been on Earth compare with the age of the Earth itself?

What the Data Mean

The group's time line sequence should ultimately match the table included in the **Useful Information**.

FOREVER AND A DAY

Questions to Think About

Scientists estimate the Earth was formed about 5 billion years ago (bya), but humans appeared only 50,000 years ago. How long did it take before life on Earth resembled what we know today? Did the events occur quickly? Were they evenly spread over time, or were they clustered at various points? How can you illustrate this?

Safety Notes

- Keep scissors away from eyes.

What to Do

1. We often use time lines to help us better understand a sequence of events. Think about your own life. How long have you been on Earth? Suppose you are 16 years old and the 3-foot piece of cash register tape represents your life. How would you show each year of your life using the paper? One way you could do this is to make a time line. First, roll the paper backward to keep it from curling. Next, fold the paper in half lengthwise and then in half again. Put a mark on each of the creases. Divide each of the marked sections into 4 equal sections. Each section represents 1 year of your life. Finally, label the bottom left hand side of the tape as 0 years and then label the first section as 1 year and so forth until the last section labeled is 16 years. See Figure 1.

Figure 1. Human time line in years.

This will give you a time line for your life. Think about what important events have happened in your life, such as your birth, first bicycle, first plane ride, starting school, learning to swim, major illnesses, special awards, first date, trips, and new siblings. Mark where these events took place on your time line. Now, you should have a time line of your life in years. What do you think this same time line would look like in seconds?

2. Can you predict how old you are in seconds? Hint: 1 year = 30,000,000 seconds and 10 years = 300,000,000 seconds. Above the 1-year mark, write 30,000,000 seconds. Mark each section of your time line at the top in seconds for each year as shown in Figure 2.

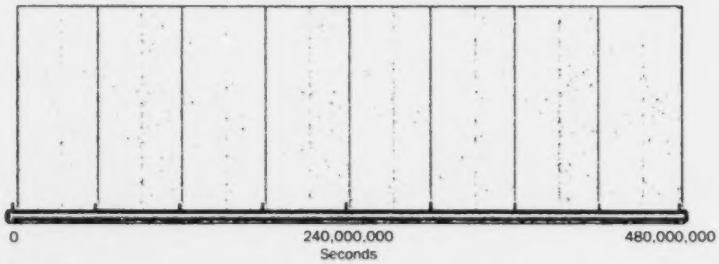


Figure 2. Human time line in seconds.

How old were you in seconds when you got your first bicycle? When you started school? What do you think about these numbers compared to using years?

3. When scientists deal with the history of the Earth, they must work with numbers even bigger than the number of seconds in your life. Do you know the oldest age that any human has ever attained? Do you know how to tell the ages of trees, people, fish, horses, turtles, rocks, cars, computers, or oranges? Do you know what the longest living tree is? If you do not know these answers, how can you find out? How do scientists determine the ages of rocks and fossils? If fossils are unearthed along the height of a mountain bed, how can scientists tell which of the fossils is older and which is more recent?

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4. As a group, write each of the following on a separate note card.

- Origin of the Earth
- First cells without nuclei appear
- First birds appear
- Oxygen in the atmosphere
- Trees appear
- Dinosaurs appear
- Mammals appear
- Humans appear
- First cells with nuclei appear
- First multicellular organisms appear

5. Tape the 12-foot piece of cash register tape to the wall. It represents 5 billion years of the Earth's history. Figure out how many inches are in one-fifth of the tape. How many years does this length represent? Mark the tape into 5 segments of 1 billion years each.

6. Discuss the events you wrote on the note cards with the members of your group. Brainstorm about the possible sequence in which they occurred over 5 billion years. Be sure that your group can support the sequence of events that you develop.

7. The events on your cards occurred during the following time periods: 4.6 bya, 3.8 bya, 2 bya, 1.4 bya, 0.7 bya, 0.065 bya, 0.35 bya, 0.235 bya, 0.220 bya, 0.00005 bya. Mark those points on your time line. Now tape the event cards in sequence above the time line.

8. Look at how each of the other groups sequenced the same events. Are they the same as your group's? Discuss the similarities and differences among the members of your group and with the other groups. Do you think you should change your group's time line? If so, make adjustments that you can support. Your facilitator will help the large group decide on a single time line.

9. Now that you have decided on a time line for the geological events, compare it to your own time line. How many times larger is the number of years the Earth has been around than your age in seconds? Are all the events evenly spaced over the years? If the events of your life occurred in clusters similar to those of the Earth's, when would they have occurred?

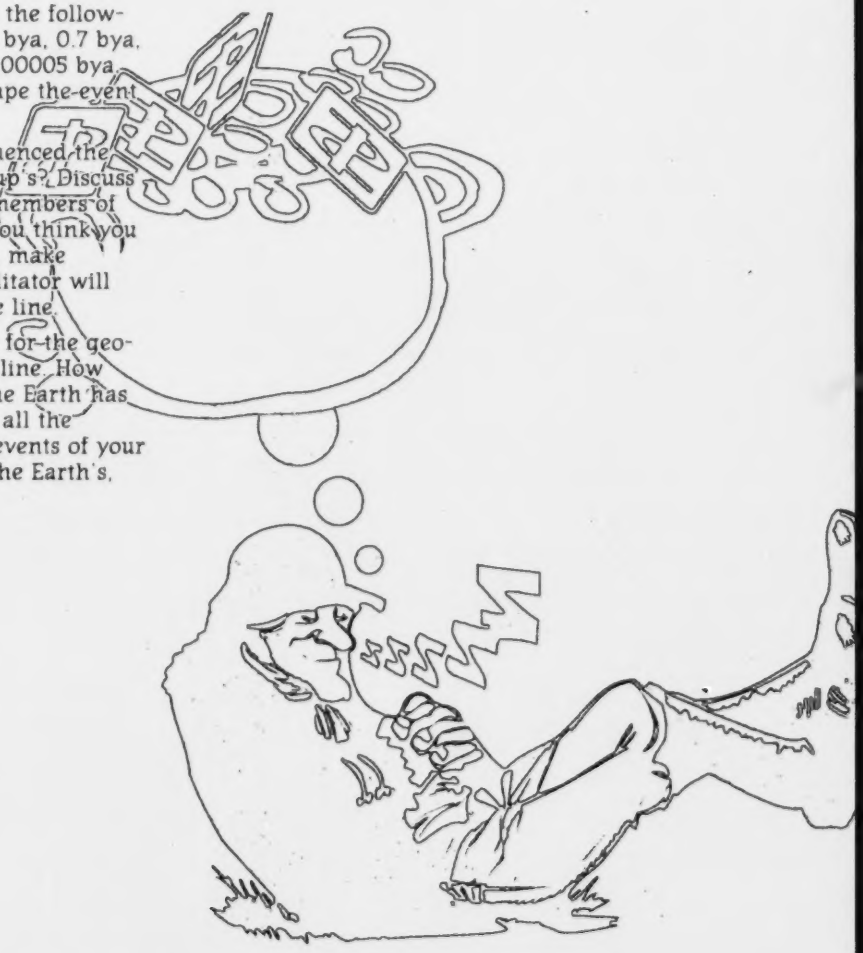
What Did You Find Out By Doing the Activity?

Before doing "Forever and a Day," did you know:

- what fossils are?
- about the age of the dinosaurs and other major events in Earth's history?

From this activity, did you discover:

- what factors have separated major Earth events?
- how scientists determine the age of the Earth?
- why the appearance of oxygen in the Earth's atmosphere is so important?
- the major divisions of time in your personal time line?
- how you could determine the age of an old toy if you didn't know when it was used?
- why determining the age of the Earth is important?
- what kinds of artifacts can be used to determine the age of the Earth?



MEGA MULTIPLES OF MICROBES

Can you imagine how wealthy you would be if you put a penny in the bank and it doubled in value every single day? What if its value doubled several times a day? Could you count that high? At what point would you be a millionaire? A billionaire?

Goal

To visualize large numbers and calculate microbial population growth.

Activity Time

60 minutes

Time to Get Ready

5 minutes

What You Need

Have the following for each team of 4:

1 pencil

1 piece of paper

1 1-lb package of rice or pinto beans

1 piece of graph paper

1 bowl

1 calculator (optional)

Getting Ready

Beans may be substituted for rice to simplify the counting process for younger children. Participants can work independently or in groups. Depending on the objectives of the activity, calculators may be permitted. Computer literate participants may program calculations of geometric growth to determine growth over time.

Useful Information

It is easy to visualize numbers of familiar things. We can estimate how many people are in a room. We can estimate the distance between two classrooms. But visualizing very large numbers is difficult. The number of microbes necessary to have an impaction humans in many cases is very large. Populations may increase from a single cell to millions of cells. They may increase to billions or trillions in a single test tube.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Use beans to count in this activity. Their larger size will be easier to count and manipulate.
- Construct a tactile diagram of a cell and graphs of the data using the materials discussed in the ***General Modifications*** section of the **Introduction**.

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind* or *Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

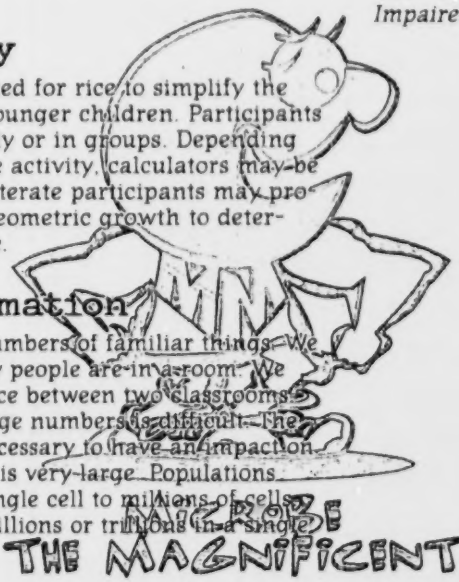
- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- Use beans for easier counting and manipulation.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.



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How to Start the Activity

° Microbes double in number each time they reproduce. This doubling produces a geometric increase in numbers of individuals. It is important for participants studying microbes to have the concept of very large numbers so they can envision the magnitude of individuals in microbial populations.

° Ask the participants to determine how much money they would have at the end of the month if they had one penny on the first of the month and it doubled every day. Answer: $10,737,418 for a month with 31 days or $5,368,709 for a month with 30 days.

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

° How could you calculate the numbers of microbes in successive generations?

° What would happen if the amount of time for a generation was changed?

° What would happen to the numbers in each generation if the length of time for the generation was doubled?

What the Data Mean

Sample Data

1. A 1-lb package of medium grain rice contains approximately 20,000 grains. A 1-lb package of pinto beans contains approximately 1200 beans.

2. After 20 generations, the new population would contain 1,048,580 microbes.

3. After 40 generations, the new population would contain 1.0995×10^{12} microbes. See Figure 1.

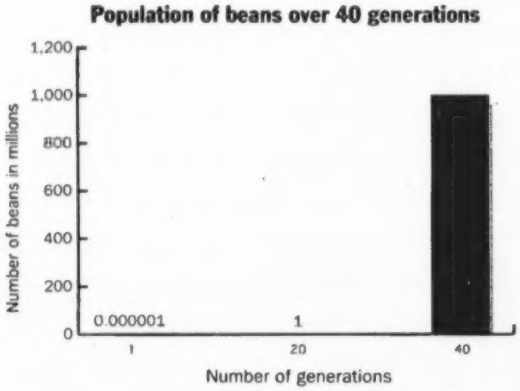

Figure 1. Graph showing the increase in the size of a population of beans after 1, 20, and 40 generations.

Answer to Question on Participant Page

4. At 120 minutes, Organisms A and B would have populations of the same size. The condition would be temporary as Organism A's shorter generation time would allow it to multiply more rapidly.

Mega Multiples of Microbes

Questions to Think About

Microbes divide, forming new cells. That is, 1 cell forms 2 cells in a certain period of time that often is called a generation. Then the 2 cells divide, forming a total of 4 cells. These 4 cells can all divide, forming a total of 8 cells. In each generation the number of cells in the microbial population doubles. See Figure 1.

Safety Notes

- None

What to Do

1. Determine the number of grains of rice in a package of rice from the grocery. Count the number of grains required to fill a measuring spoon. Using spoonfuls, determine the number of spoons of rice required to fill a small cup or glass. Then calculate the number of grains of rice in the cup. Finally, measure the rice from the package by filling and refilling the cup. Approximately how many grains of rice are in a package of rice? How many packages of rice would you need to have a million grains of rice? How many for a billion?

2. Determine how many cells are formed from a single cell in 20 generations. Do this by beginning with 1 cell and doubling it (multiply 1 by 2). This is the first generation. Then the number 2 is multiplied by 2 for the number of cells at the end of the second generation. This number is multiplied by 2 to determine the number for the third generation, and so on to the 20th generation. Compare your numbers with those obtained by the others in your group. Correct any mistakes. Construct a graph of your results.

3. What would happen if you were to calculate the number of individuals produced after 40 generations rather than 20? How could you graph this information to keep it on a single page? Could you make a graph to include time if you know a single generation takes one-half hour or some other time period to reproduce? What conditions might affect the number of individuals in microbial populations?

4. From the information you have on this scenario, develop a hypothesis that could be tested in an experiment that gathers quantitative data. Be able to explain your hypothesis. For example, Organism A has a generation time of 20 minutes. Organism B has a generation time of 30 minutes. At the starting time, 100 individuals of Organism A and 400 individuals of Organism B are placed in optimum conditions and begin to reproduce. Can you determine when, or if, both populations will ever be the same size?

What Did You Find Out By Doing the Activity?

Before doing "Mega Multiples of Microbes," did you know:

- the huge numbers you must use to count microbes?
- how these large numbers in microbe populations are calculated?

From this activity, did you discover:

- how the growth rate of microbes is calculated?
- how long it takes for different microbes to multiply?
- why determining the growth rate for microbes is important?
- how microbes can be eliminated from surfaces even though they grow at rapid rates?
- what happens to older cells as the new cells continue to multiply?

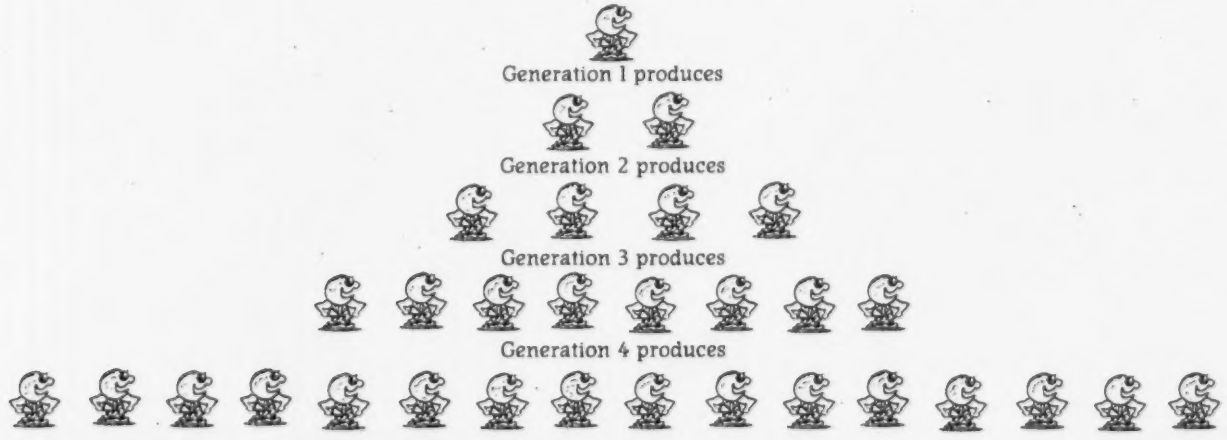

Figure 1. Diagram of population growth over four generations.

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NATURAL SELECTION

Is everyone you know exactly the same? Or are some taller or shorter than others? Do some have darker skin? Are some heavier? Do their differences make them better at some things, but not well-suited for others?

Goal

To demonstrate that natural selection results in populations different from the original.

Activity Time

50 minutes

Time to Get Ready

15 minutes

What You Need

Have the following for each team of 4:

5 cups of various sizes of beans or different colored beads
1 pencil
5 wooden dowels with assorted diameters
2 pieces of paper
2 Styrofoam™ bowls

Getting Ready

- Lentils, pinto beans, kidney beans, navy beans, red beans, black beans, great northern beans, split-green peas, and black-eyed peas work well for this activity. Dry, multi-bean soup mixes also can be used.
- Lima and garbanzo beans are not advised. They tend to clog the holes in the bowl.
- Use the largest Styrofoam™ bowls available. Meat trays may be used in their place.
- Combine the packages of beans and distribute the mixed samples to each group of participants.

Useful Information

If you look at the people around you, are they all the same? What would happen if we lived in a world where all the food was kept 8 feet off the ground and there was absolutely no way you could get it if you weren't tall enough? Most likely, the short people would die off. The taller ones would multiply. And before long, instead of a population of people of all sizes, you would have a population of only tall people. Living things that are best-suited, or adapted, to their environment survive and multiply. Those that are not don't survive. This process is known as natural selection. Within a population of microbes, many environmental factors such as temperature, pH, nutrients, light, magnetism, radiation, and chemical agents can cause some individuals to die. Those that survive go on to produce hardier future generations. Those factors that determine which microbes survive or which do not are called "selective pressures."

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Allow for participants to touch the various beans for size and shape. This provides a better understanding of the variable and allows for independent counting.
- Emphasize class and group discussions. The cause and effect presented in this activity will enable the participant to grasp the concept easily. References to how natural selection affects us daily will strengthen the concept.
- Use the beans to your advantage. They can be used to create the chart and the graphs. For the chart, use a heavy piece of cardboard and create a graph outline using yarn. The beans could then be glued in the correct group amounts to the chart. The graphs could be created a similar way, however a bar graph will be more feasible.
- Construct bar graphs outlining the bars with heavy string. Fill the bars in with beans.

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- See the ***General Modifications*** for *Physically Impaired* listed in the **Introduction**, page V.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

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How to Start the Activity

- Provide the participants with a mixture of beans and a Styrofoam™ bowl. Have them punch a hole in the bottom of the bowl with their pencil. Instruct them to place beans in the bowl and shake. Which ones pass through the hole? Why? Why don't the others?
- What if the beans were a population of microbes and only the types that stay in the bowl survive to reproduce? Would the next generation look like the one in the bowl?
- Help participants make a table of generations as described in Step 4 of **What to Do** on the **Participant Page**.

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- What if the hole was larger than each bean?
- What if the hole was smaller than each bean?
- Which bean population will increase most significantly? Why?
- What changes might occur in microbes that would cause selective pressure?

What the Data Mean

Table 1. Generation Totals

	Generation	1	1	2	2	3	3	4	4	5	5
Bean-Rice Mixture	Starting Number	Number left	Doubled	Number left	Doubled	Number left	Doubled	Number left	Doubled	Number left	Doubled
Lentil	5	2	4	4	8	2	4	1	2	2	4
Split-green pea	5	3	6	4	8	6	12	10	20	11	22
Rice	5	2	4	2	4	2	4	1	2	0	0
Pinto	5	5	10	10	20	20	40	40	80	80	160

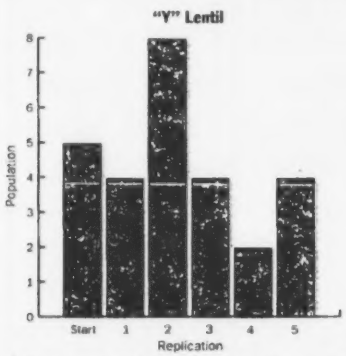

Figure 1. Graph of lentil replication.

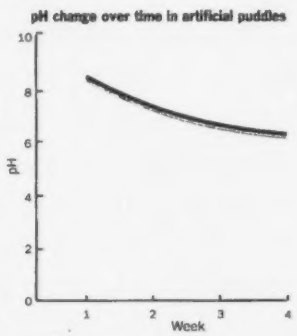

Figure 2. Graph of split-green pea replication.

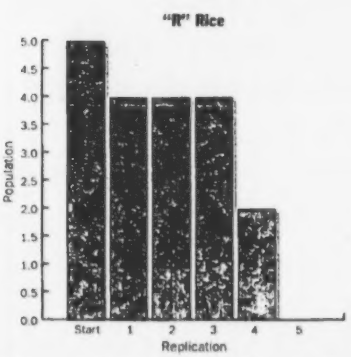

Figure 3. Graph of rice replication.

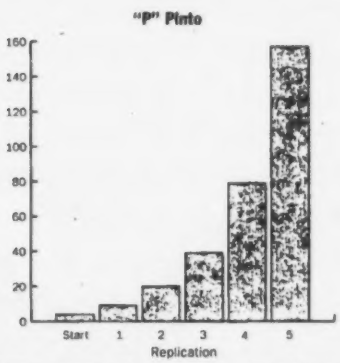

Figure 4. Graph of pinto bean replication.

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NATURAL SELECTION

Questions to Think About

Look at the people around you. Are they all the same? Or are some taller or shorter than others? Do some have darker skin? Are some heavier? Do their differences make them better at some things, but not well suited for others? What would happen if we lived in a world where all the food was kept 8 feet off the ground and there was absolutely no way you could get it if you weren't tall enough?

Safety Notes

- Exercise care with a pencil when punching holes in the Styrofoam™.

What to Do

1. Use your pencil or 1 of the different-sized dowels to punch 6 different-sized holes in the bottom of your unused bowl. A living population of microbes would include millions, billions, or even more individuals, but you will work with much smaller numbers. To create the initial "microbe" population, select 5 beans of each type. Place this population of 25 in the bowl.

2. Shake the bowl 15 times and note which beans fall through the holes as shown in Figure 1. You will probably get the best results if you shake the bowl from side to side similar to the motion you use just before you throw dice. A group recorder must keep accurate records of the numbers that fall as well as those remaining. The ones that fall through the holes are considered dead. The ones in the bowl are considered the first generation and will be used to represent the "parents" for the next generation. Only "microbes" that survive reproduce. So, for each of the beans that remain in the bowl, add another one of the same type to indicate that the "microbe" reproduced. Look at the beans/microbes that fell out of the bowl. Did all types fall out in the same numbers? Look at your new population in the bowl. Does it resemble your original or are the proportions different?

3. Repeat the same procedure with the population from the first generation. Shake the bowl 15 times. Count and record the number of beans both in the bowl and those falling through the holes. Again duplicate the beans remaining in the bowl. Look at the new population in the bowl. Is it changing? How? After 5 generations, analyze the data. Graph the results.

4. Compare the numbers of each type of bean in each generation to see if there are changes in the proportions. Organize this information in a table. List the types of beans in the first column. Put their starting numbers in the second column. In the third column, write the numbers of each type of bean left after shaking. Multiply the numbers by 2 and write the quantities in the next column. Continue the table for each generation. Create graphs to show your results. Once the graphs have been completed, predict the numbers in the next 2 generations if the same trends occur.

What Did You Find Out By Doing the Activity?

Before doing "Natural Selection," did you know:

- some factors that determine if an organism can live in an environment?
- what could lead to the extinction of a group of organisms?
- how organisms adapt to new environments?

From this activity, did you discover:

- why organisms evolve over time?
- how natural selection works in a population of microbes?
- what factors determine your own survival in your everyday life?
- some factors that make you different from your parents and how to explain that difference?

Figure 1. Shaking the bowl of beans.

Biosphere in a Bottle

Have you ever dug a hole to plant a tree or bury something? Did you notice differences in the color of the soil? Why would the soil be different below the surface?

Goal

To investigate microbes that exist in a column of mud and the role of light in their survival.

Activity Time

3 to 8 weeks

Time to Get Ready

Six weeks before the activity: 1 hour
One day before the activity: 1 hour
Day of the activity: 30 minutes

What You Need

Have the following for the group:

1 lamp with 40- or 60-watt light bulb (optional)

1 roll of masking tape

Have the following for each team of 4:

4 wide-mouth, 2-quart jars or 2-L soda bottles

4 10 x 10-cm aluminum foil squares

1 permanent marking pen

1 trowel

1 small bucket

1 funnel

1 8-ounce measuring cup

1 small scoop or shovel

5 cups mud or sand from 4 different mud sources such as a pond, marsh, lake, garden, or forest

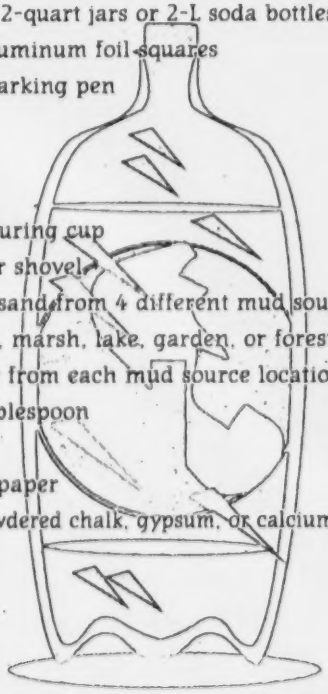
5 cups of water from each mud source location used

1 measuring tablespoon

1 paint stirrer

1 sheet of newspaper

1 tablespoon powdered chalk, gypsum, or calcium sulfate



Getting Ready

Six weeks before the activity

- Assemble a bottle or jar of mud as indicated in the **Participant Page**. Set it in a well-lit area until the group meets.
- Plastic soda bottles can be used instead of jars. Remove the top with scissors. See Figure 1. The bottles can be sealed using foil or plastic wrap and an elastic band. The remaining top can be used as a funnel.

One day before the activity

- Gather soil from a variety of local areas such as a forest, garden or sediment from lake or pond.
- Use a pencil sharpener to powder the chalk. Gypsum or calcium sulfate may be substituted for powdered chalk.
- If time permits, shred the newspaper into strips no greater than 10-cm (4-inches) wide.
- Set out materials for each group.

The day of the activity

- Assemble a second bottle or jar of mud as indicated in the **Participant Page**.

Figure 1. Diagram of a cut soda bottle.

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Useful Information

The biosphere is the Earth's life support system. Many organisms play important roles in the system. Microorganisms can be found everywhere. But like plants and animals, different kinds thrive in different places. Though difficult to see, pigmented photosynthetic bacteria are found in soil. Light provides the energy they need to grow. Two very important features of light that affect the growth of microbes are intensity and wavelength or color. Photosynthetic microorganisms live in specific light intensities. Too much light is as bad as no light. High light intensities retard photosynthesis and may cause organisms to overheat. White light is made up of many colors. A rainbow or prism reveals these colors. Different photosynthetic bacteria have different pigments that absorb different colors of light. As a result, they require different colored light to grow. For example, green algae do not grow well in green light. Oxygen requirements vary from microorganism to microorganism. An oxygen layer found at the top of mud is called an oxic zone. Further from the surface, the mud lacks oxygen, in an anoxic zone. Bacteria that require oxygen are called aerobic and live in the oxic zone, while bacteria that cannot tolerate oxygen are called anaerobic and live in the anoxic zone. Photosynthetic cyanobacteria produce rather than require oxygen. Other photosynthetic green and purple bacteria often produce sulfur or sulfur-containing compounds in place of oxygen.

In this activity, the biosphere column also is called a Winogradski Column. It is named after the Russian microbiologist Sergei Winogradski. Different substances added to the column change the microbe growth. For instance, ground chalk is a source of carbonate that starts photosynthesis. Egg shells have sulfate that makes hydrogen sulfide gas and anaerobic conditions. This is the gas that smells like rotten eggs.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Allow participants to touch and describe the textures of the different soils (such as moist, dry, dense, and porous) gathered for a better understanding of the variable. This will make it easier for the participant to develop independent hypotheses and conclusions.
- Place all measuring devices to the right and the marked soils to the left for consistency in the setup.
- Replace group or class discussions with daily observations recorded in a journal. Discuss specific observations. Make repeated references to color, texture, size, and moisture. Individuals who are blind have a good understanding of color and will appreciate the detailed observations. Use the other senses for clarification with statements such as, "This is the gas that smells like rotten eggs."

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- See the ***General Modifications*** for *Physically Impaired* listed in the **Introduction**, page V.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

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How to Start the Activity

Show the participants a fully-developed biosphere in a bottle made 6 weeks earlier and a freshly-made bottle. Tell them the bottles contain exactly the same materials. Ask them to compare the bottles.

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- Do the bottles look like they contain the same materials?
- If they contain the same materials, why do they look different?
- What do you think the different colors in the bottles represent?
- What is the difference between the 2 bottles?
- What is the same?

Ask the following questions at the end of the first session. How would you test the hypothesis that light is essential for the growth of photosynthetic microbes? How would you test the hypothesis that photosynthetic microorganisms can be found everywhere even if you can't see them?

What the Data Mean

Explanations for results of the 6-week column growth in Figure 2 are listed below.

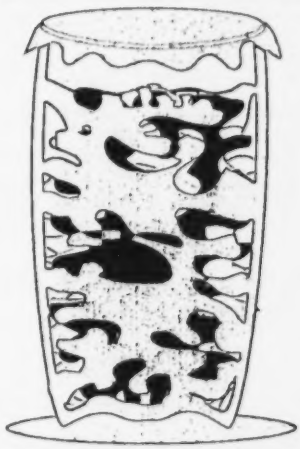


Figure 2. Sample column showing areas of bacterial growth after 6 weeks.

- The different colors in the mud represent the presence of different photosynthetic microbes.
- Red and orange patches are purple phototropic bacteria. Green patches in the oxic zone are cyanobacteria and algae. Olive-green patches in anoxic zones are green sulfur bacteria. The white color is sulfur produced from hydrogen sulfide by bacteria that do not produce oxygen when they photosynthesize and other sulfide-oxidizing bacteria. Hydrogen sulfide is produced by sulfate-reducing bacteria. The black patches are iron sulfide formed by sulfate-reducing bacteria.
- The patchiness is the result of the formation of microenvironments. The microenvironment is the environment right next to a microbial cell or group of cells.

Explanations for results of possible participant-designed experiments.

- A bottle kept in the dark will not grow photosynthetic bacteria because light energy is critical to the development of photosynthetic organisms. However, other types of bacteria may grow. Even some phototrophs can produce energy for growth by other means in the dark.
- A bottle kept in direct sunlight may not show any growth because high light intensity retards photosynthesis, and the extreme heat can stifle growth.
- A bottle kept in extreme heat will not show any growth unless the soil comes from a hot spring, because most organisms cannot survive temperatures greater than 50°C (120°F).
- If the bottles are covered with colored cellophane, different microbes will grow, as they require different light colors. For instance, purple sulfur bacteria need red to near infrared light, green sulfur bacteria need green or red light, and cyanobacteria and green algae need red light.

Biosphere in a Bottle

Questions to Think About

Think about your neighborhood. How many different living things do you see? Where are they located? Why are some in one place, but not in others? What determines where living things can survive? Have you ever noticed patches of different colors in the soil when you dug a hole? What causes those colors? Why are they not distributed evenly throughout the hole?

Safety Notes

- Wash hands before and after the activity.
- Use caution when working with soil and glass bottles.
- Latex or rubber gloves should be worn if a participant has an open cut or wound.
- Use chalk where possible. Gypsum or calcium sulfate can irritate the skin.

What to Do

1. If it has not already been done, shred a full sheet of newspaper into very small pieces. Set it aside.
2. In a small bucket, add 5 or 6 cups of soil. Pick out all the sticks, leaves, and rocks. Stirring with the paint stirrer, slowly add water to the soil until it becomes the consistency of thick cream. The amount of water needed will depend on how moist the soil was at first. Add the shredded newspaper and 1 tablespoon of powdered chalk to the mud slurry. Mix the contents gently. Make sure the mixture is fluid so it will flow easily through the funnel.
3. Remove any existing labels from your bottle. Make a new label for your bottle with the name of the mud source on it. Set the funnel into the mouth of the bottle. Tape it securely in place. Scoop approximately 1 centimeter (cm) of the mud mixture into the bottle. With one hand covering the opening of the bottle, and the other holding the base of the bottle, gently tap the base on a table to settle the mixture evenly. Continue to fill the bottle, gently tapping every few centimeters until it is filled to within 4 or 5 cm of the top. Cover with foil. See Figure 1.

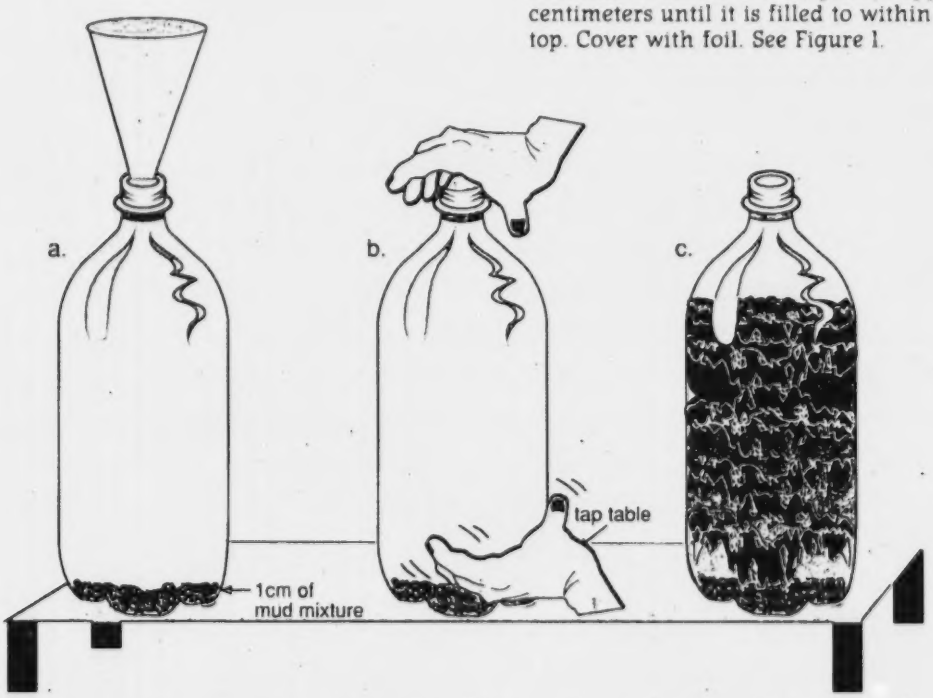


Figure 1. Biosphere setup. Figure 1a and b show how to add the mud to the column. Figure 1c shows the final setup.

4. Repeat the above process to fill each of your bottles. Use mud from different places for each bottle. Be sure each is properly labeled.

5. Take your biosphere bottle home and place it in a well-lit place away from direct sunlight. A window with a northern exposure works best. If you do not have a window, place the bottle about 60 cm (24 inches) from a 40- to 60-watt lamp. For best results, don't expose the bottle to direct sunlight or intense heat.

6. Keep the bottle in one position. Do not move it. Observe the bottle daily, looking for color or other changes in the mud. Be patient. It takes about 6 weeks to notice any color changes, but you should see other changes sooner, such as the formation of gas bubbles. What causes this? What gas could it be? Write your observations in a journal or notebook. Draw, label, and color a picture of the column at the end of each week. Why are there different colors in the bottle? What makes the red, orange, green, white, and black colors? Why do some colors appear in one part of the bottle and not another?

7. What other questions come from your results? To what other topics is this activity related? What did you learn from this activity? How is this activity related to your life? What did your results show?

8. How can you learn more about photosynthetic microorganisms? What steps would you use? What if you used different colored bottles or wrapped the clear bottles in colored cellophane? What if you added different nutritional sources like straw, grass, filter paper, baking soda, crushed vitamins, carbonated beverages, or yeast extract to the mud? What if you put the bottle in the dark? What if you put the bottle under intense heat?

9. Design a new experiment based on data you gathered or questions you asked during this activity. Develop a hypothesis that can be tested in a controlled experiment. Write a procedure in a numbered list. What is your control? What variables are important? How many trials have you included? What will you measure? How can you show your results?

What Did You Find Out By Doing the Activity?

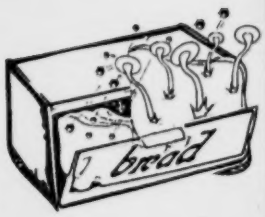
Before doing "Biosphere in a Bottle," did you know:

- that there are living organisms in water?
- that there are living organisms in mud?
- what the basic requirements for life are?

From this activity, did you discover:

- that living organisms survive in water? in mud?
- why the number of living organisms appearing in the bottles is different as time passes?
- why the mud layers appear to be different colors?
- how to find signs of living organisms in the bottles?
- how to find out why organisms grow in certain places in the bottle and not in other places?
- that life can exist in the slime found on a sidewalk?
- that different slimes can be good or bad for the environment?
- that organisms which are able to survive in a bottle require many of the same basic nutrients that they need to live?

Bread Box Nightmares



Have you ever opened a bread bag only to find the bread inside covered with mold? Why does that happen? What is mold? How does it grow?

Goal

To investigate the factors needed for fungi to grow and develop.

Activity Time

14 days

Time to Get Ready

30 minutes

What You Need

Have the following for the entire group:

1 hot plate or stove
1 stirring rod or spoon
1 250-mL beaker or small sauce pan
100 g sugar

Have the following for each team of 4:

3 50-mL beakers or small cups
3 pipettes or eye droppers
20 mL prepared sugar solution
20 mL lemon juice
20 mL tap water
4 slices of white bread
4 slices of assorted breads such as bakery, rye, or wheat
8 zippered, plastic bags
1 permanent marking pen

Getting Ready

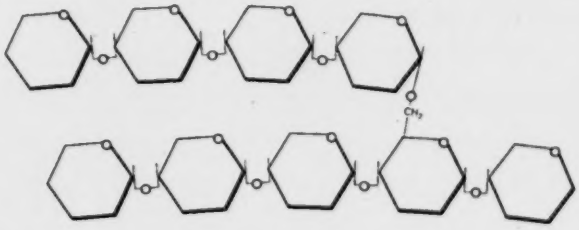
- Fill the 250-mL beaker or sauce pan with 100 mL of water. Add approximately 100 g of sugar to the water. Heat the mixture until the sugar is dissolved. Allow the solution to cool for 5 minutes.
- For each group, fill 1 50-mL beaker or small cup with 20 mL of tap water, 1 50-mL beaker with 20 mL of lemon juice, and 1 50-mL beaker with the prepared "Sugar Water."
- Set out materials for each group.
- Potato slices can be substituted for bread slices.

Useful Information

Fungi are decomposers. As such, most release enzymes to digest the food around them. They keep the ecosystem balanced by breaking down dead organisms. They also break down the wastes of living things. To survive, they need moisture, food, warmth, and darkness.

Bread contains large quantities of starch that is a great food source for bread molds. These molds grow not only on breads, but also on fruit. They are generally greenish or black and fuzzy. They digest starch and make glucose. See Figure 1. Glucose is a building block of starch. The glucose is then used by the fungi and bacteria as an energy source.

Glucose



Starch

Figure 1. Glucose and starch molecules. Notice that glucose is a basic unit of the longer starch molecule.

Bread molds produce spores. The spores are stored in cases which are on thin stalks. When the cases break, hundreds of spores are released into the air. If the spores land on a suitable place, they produce more mold. See Figure 2.

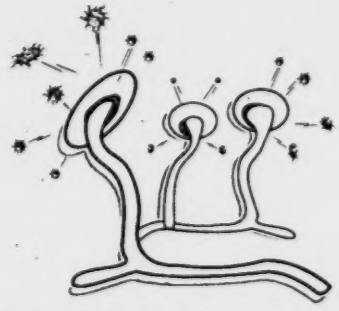


Figure 2. Releasing spores

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

° Allow the participants to touch and smell the different types of bread. Sensory stimulation is beneficial to the participant achieving a better understanding of the activity. Discuss the distinct characteristics of the bread, such as texture and density. References to common experiences such as, "Have you ever opened a container of homemade spaghetti sauce? What did you find?" are important to understanding the basic concept. These sensory prompts will allow the participants to think independently and develop their own hypotheses.

° Build a tactile model of the glucose and/or the sporangium. See the **Introduction** for suggested materials.

° Construct a bar graph showing the progression of mold growth with educational counters called cubed manipulatives.

Deaf or Hard-of-Hearing

° See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

° See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

° See the ***General Modifications*** for *Physically Impaired* listed in the **Introduction**, page V.

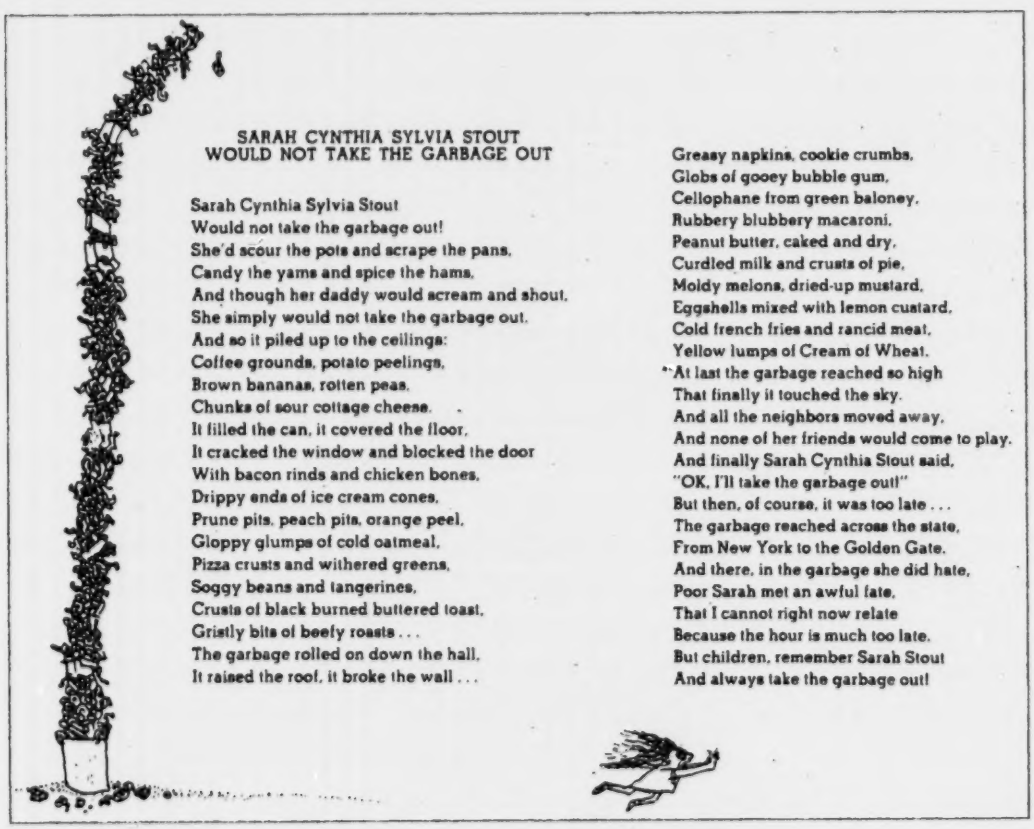
Cognitively Impaired

° See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

How to Start the Activity

° As an introduction, the poem "Sarah Cynthia Sylvia Stout Would Not Take the Garbage Out!" by Shel Silverstein may be used to generate discussions about garbage and fungi growth. See Figure 3.

° Set out 4 pieces of bread. Have the participants examine them closely.



SARAH CYNTHIA SYLVIA STOUT
WOULD NOT TAKE THE GARBAGE OUT

Sarah Cynthia Sylvia Stout
Would not take the garbage out!
She'd scour the pots and scrape the pans,
Candy the yams and spice the hams,
And though her daddy would scream and shout,
She simply would not take the garbage out.
And so it piled up to the ceilings:
Coffee grounds, potato peelings,
Brown bananas, rotten peas,
Chunks of sour cottage cheese.
It filled the can, it covered the floor,
It cracked the window and blocked the door
With bacon rinds and chicken bones,
Drippy ends of ice cream cones,
Prune pits, peach pits, orange peel,
Gloppy glumps of cold oatmeal,
Pizza crusts and withered greens,
Soggy beans and tangerines,
Crusts of black burned buttered toast,
Gristly bits of beefy roasts . . .
The garbage rolled on down the hall,
It raised the roof, it broke the wall . . .

Greasy napkins, cookie crumbs,
Globs of gooey bubble gum,
Cellophane from green baloney,
Rubbery blubbery macaroni,
Peanut butter, caked and dry,
Curdled milk and crusts of pie,
Moldy melons, dried-up mustard,
Eggshells mixed with lemon custard,
Cold french fries and rancid meat,
Yellow lumps of Cream of Wheat.
At last the garbage reached so high
That finally it touched the sky.
And all the neighbors moved away,
And none of her friends would come to play.
And finally Sarah Cynthia Stout said,
"OK, I'll take the garbage out!"
But then, of course, it was too late . . .
The garbage reached across the state,
From New York to the Golden Gate.
And there, in the garbage she did hate,
Poor Sarah met an awful fate,
That I cannot right now relate
Because the hour is much too late.
But children, remember Sarah Stout
And always take the garbage out!

Figure 3. "Sarah Cynthia Sylvia Stout Would Not Take the Garbage Out!" from *Where the Sidewalk Ends the poems and drawings of Shel Silverstein*. Acknowledgment: COPYRIGHT, 1974 B EVIL EYE MUSIC, INC. SELECTION MAY NOT BE RE-ILLUSTRATED. Used by permission of HarperCollins Publishers.

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Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- Is anything growing on this bread?
- How could you encourage something to grow on the bread?
- Would it matter what type of bread you used?

What the Data Mean

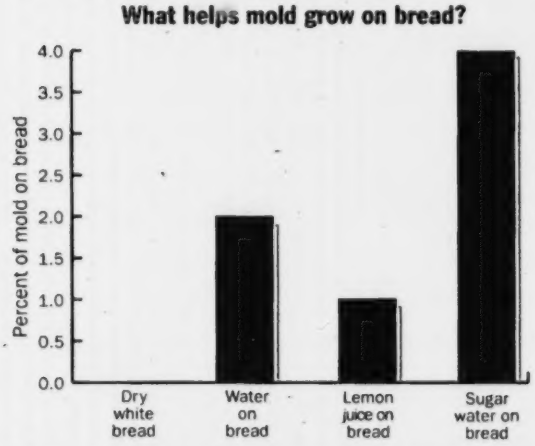

Figure 4. This graph shows that sugar water encourages growth of mold on bread.

For More Information

Access Excellence. Teaching Ideas. Fungus among us. *http://www.gene.com/ae/atg/released/0347-TishTaylor/description.html*
This site is dedicated to teachers and provides lesson plans, resources, and an activities exchange for biology curriculum.

Hawke, C. (1997). Focus on *Listeria*: A foodborne bacterium. *Pasteur Perspectives, (3),* 1-2.

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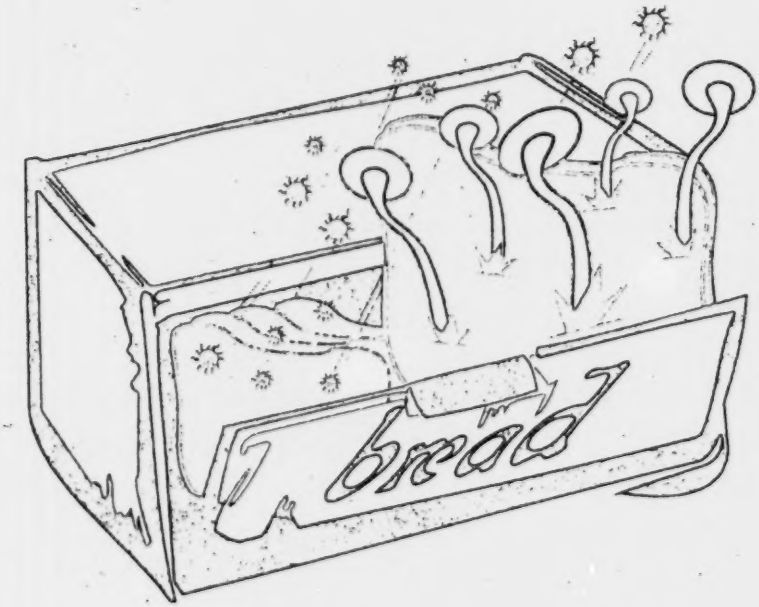
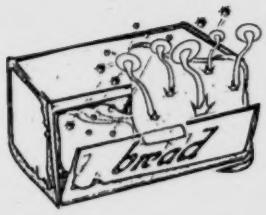


BREAD BOX NIGHTMARES



Questions to Think About

Have you ever been asked to clean out the refrigerator? Have you ever opened a container of homemade spaghetti sauce or some other food that's been in the refrigerator too long? Sometimes you open a container of food, and what do you find? Fungi! You might say this food is "moldy." Mold is a type of fungi. Is it living? If it is, what does it need to grow?

Safety Notes

- Wash hands before and after the activity.
- Do not eat materials from the activity.
- Make sure the bags are sealed tightly, and do not open them once the fungus begins to grow.
- Throw all materials away at the completion of the activity.
- Food, drinks, and gum are not allowed.
- Use caution when working with glass beakers.
- Use caution when working with hot plates and hot liquids.

What to Do

1. Label 1 zippered, plastic bag as "Dry White Bread," 1 as "Water on White Bread," 1 as "Lemon Juice on White Bread," and 1 as "Sugar Water on White Bread." Put your group name on all 4 bags. Place a slice of dry white bread in the bag marked "Dry Bread" and seal it. Sprinkle 20 drops of water on another slice of white bread. Be sure not to overmoisten the bread. It should only be damp. Place the slice of bread in the bag marked "Water" and seal it. Sprinkle 20 drops of lemon juice on another slice of white bread. Place it in the bag marked "Lemon Juice" and seal it. Sprinkle 20 drops of sugar water on the last slice of white bread. Place the slice of bread in the bag marked "Sugar Water" and seal it.

2. Repeat the steps above, but use a different type of bread in the other 4 bags. Be sure to label the bags so you will know what is in them.

3. Place all 8 bags in a dark, warm (30°C) place. Check on them daily for 2 weeks. Record your results on a chart. Construct a graph of the results. Can you see evidence of a decomposer at work on the bread? What would happen to the bread if you left it indefinitely? You may want to try this and see what happens.

4. What questions come from your results? To what other topics is this activity related? What did you learn from this activity? How does this activity relate to your life? What did your graph show?

5. How can you learn more about the requirements of fungi? What procedures would you use? What would you measure? What if you used another kind of bread? What if you sprinkled other liquids on the bread? What if you altered the temperatures? What if you left them exposed to light? What if you changed the amount of liquid sprinkled on the bread? What if the bread had preservatives in it? Could you design an experiment to test a new hypothesis or question?

6. Design a new experiment based on data you gathered or questions you asked during this investigation. Develop a hypothesis that can be tested in a controlled experiment. Write a procedure in a numbered list. What is your control? What variables are important? How many trials have you included? What will you measure? How can you show your results in a graph?

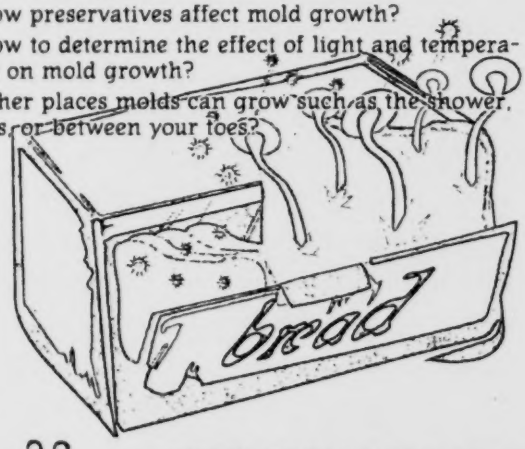
What Did You Find Out By Doing the Activity?

Before doing "Bread Box Nightmares," did you know:

- what mold is?
- what it needs to grow?
- that not all molds look alike?
- where mold can grow besides food surfaces?

From this activity, did you discover:

- what different molds look like?
- how mold grows?
- how preservatives affect mold growth?
- how to determine the effect of light and temperature on mold growth?
- other places molds can grow such as the shower, trees or between your toes?



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CAN MICROBES TELL THE DIFFERENCE?

Can you tell which foods are good for you just by tasting? Do two sweet-tasting foods have the same nutritional value?

Goal

To compare the energy content of various sweeteners by measuring yeast's production of carbon dioxide when using sweeteners as food.

Activity Time

60 minutes

Time to Get Ready

20 minutes

What You Need

Have the following for each team of 3 or 4:

1 microviewer or microscope (optional)
1 slide and cover slip if using microscope (optional)
photographs of yeast (optional)
4 to 7 zippered, plastic freezer bags
10 teaspoons rapid rise yeast
1 permanent marking pen
1 measuring teaspoon
1 metric ruler
1 8-ounce measuring cup
1 small container of very warm water
1 L clear, regular soda
1 L clear, diet soda
2 packets sugar (2 teaspoons)
2 packets of Sweet 'n Low® (saccharin)
2 packets of Equal® (aspartame)
variety of other "sweet" products such as grape juice, lemon juice, non-fruit drinks which contain fructose
4 3-ounce paper cups
1 roll of masking tape
1 1-L container (optional)

Getting Ready

Set out materials for each group, or set up a central area for one member of each group to collect materials for the group.

Useful Information

Yeast are living organisms and have similarities to humans. They consume sugar for energy and release carbon dioxide. The amount of carbon dioxide produced indicates the amount of energy provided. Artificial sweeteners like aspartame and saccharin, though sweet-tasting, do not contain sugar. Only small bits of these sweeteners are needed to give the same taste as a large amount of sugar. Yeast can break down aspartame, but it provides little energy because so little energy is present. Saccharin's structure is different, however. Neither we nor yeast can break it down.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

° Provide a wealth of references on the speed of the gas production. The participant will appreciate the detailed observations. Holding the bags before, during, and after the activity will give the participant an excellent understanding of the activity.

° Construct a tactile diagram of "yeast budding." See the **Introduction** for suggested materials for construction. See Figure 1.

Figure 1. Yeast budding.

Deaf or Hard-of-Hearing

- Introduce the relationship between the number of calories in sweeteners as an energy source. Emphasize this relationship when participants taste the sweeteners.

Mobility Impaired

- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- See the ***General Modifications*** for *Physically Impaired* listed in the **Introduction**, page V.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

For More Information

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Nisimoto, K. (1993). Fermentation laboratory: All living organisms need food. *Favorite Labs from Outstanding Teachers, Volume II.* Reston, VA: NABT Publications, 83-88.

Stolberg, S.G. (1998). Bid to absolve saccharin is rebuffed by U.S. panel. *The New York Times, CXLVIII*(51,328).

Wilford, J.N. (1996). Beer of kings was no brackish brew, archaeologist says. *The New York Times, CXLV*(50,470).

Wu, C. (1997). Yeast make berry sweet sugar substitute. *Science News, 151*(19), 284.

How to Start the Activity

Provide each group of participants with a few granules of yeast. Some participants may be aware that it is yeast. Others may not be. Even if they are aware that it is yeast, they may never have thought of it as a living organism with the basic needs of water and food for energy. Ask them to discuss the following questions.

- How would you describe what I just provided to you?
- Do you know what it is?
- Have you seen it before?
- Do you think it is alive?
- What do living organisms need to survive?
- What provides living organisms with their energy to carry on life functions?
- Are some energy sources better than others?

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- What will happen if we add water to these granules? Sugar and water?
- If yeast is a living organism, what does it use for an energy source?
- Do diet foods supply the same amounts of energy as natural foods?
- How can you measure the by-products of yeast metabolism?

What the Data Mean

The following results may be seen in the various bags.

- Diet soda does not produce gas.
- Regular soda will produce slightly less gas than sugar.
- Over time, more sugar will permit more gas generation.
- Simple sugars, like dextrose and fructose, cause faster initial gas production than sucrose.
- Both Sweet 'n Low® and Equal® contain maltodextrose in addition to their respective artificial sweeteners. Both produce gas at faster rates than sugar initially as the yeast uses the maltodextrose. Gas production stops after a short period of time.
- Fruit drink results will vary due to the amount of natural sugar in the fruit, amount of sugar added in processing, and acidity.
- Starting with more yeast will initially increase the rate and amount of gas production.
- Given sufficient time and expansion space, gas production will stop in each of the bags.

CAN MICROBES TELL THE DIFFERENCE?

Questions to Think About

Can you tell the difference between food and non-food substances? What is a food? Why do we eat it? How do you know the difference between food and non-food substances? What is in diet drinks? What would happen if you consumed only diet cola for a week? What is in sugar substitutes? Yeast are microscopic living organisms. Do yeast need food? If they do, what food do they use? What else besides food, would yeast require to live?

Safety Notes

- Wash hands before and after the activity.
- Food and gum are not allowed.
- Discard used plastic bags in the trash at the conclusion of the activity.

What to Do

1. Closely examine some of the granular yeast. Record your observations. Put a small number of grains of yeast and a few teaspoons of water in a zippered, plastic freezer bag. What happened to the grains? Is the water mixture clear or cloudy? If a microscope is available, put a drop of the water mixture on a slide with a cover slip and examine it under magnification. What do you see? What did the water do to the granules? Is water necessary for life? Are the granules you placed in the water actually single yeast cells? Yeast are very small and have a definite structure which can be seen under a microscope. If no microscope is available, study photographs of yeast cells.

2. Water is not the only requirement for life. To live, organisms must have an energy source. In front of you are several sweeteners and zippered, plastic freezer bags. The sweetener sugar is a known quick energy source. Are the other sweeteners energy sources? How would you test to see if they are energy sources using yeast and the bags?

3. Before you begin your experiment, determine whether your bags will leak when filled with water. Fill each bag part way with water, seal the bag, and turn it in every direction to make sure there are no tears in the bag. If water leaks from any tear in the bag, you will need to cover the tear with tape. If the leak comes from the zippered seal, cover the seal with tape once you have added the ingredients.

4. A possible experimental setup would include 4 bags: 1 control and 3 experimental bags. Each bag should have the same amount of liquid and 1 teaspoon of yeast. Bag #1 would be the control and contain warm water, yeast, and no sweetener. Why? Bags #2, #3, and #4 would each have a different sweetener such as sugar, Sweet 'n Low®, Equal®, diet soda, regular soda, or fruit juice. If you are testing one of the powdered sweeteners, use warm water with your sweetener and yeast mixture. If you are testing a sweetened liquid, just include the liquid and yeast without water. Why? See Figure 1.

5. After adding a different sweetener to each of the bags, carefully seal the bags trapping as little air as possible. Mix the contents well. Keep the contents of the bags at a constant temperature by placing them on an overhead, or holding them in your hands or under your arms. You will monitor the bags every 10 minutes, so make note of the time.

6. While you wait, taste a sample from the unused portions of each of the sweeteners you tested. Which is sweetest? Which do you think will provide the most energy for the yeast? Write down your predictions.

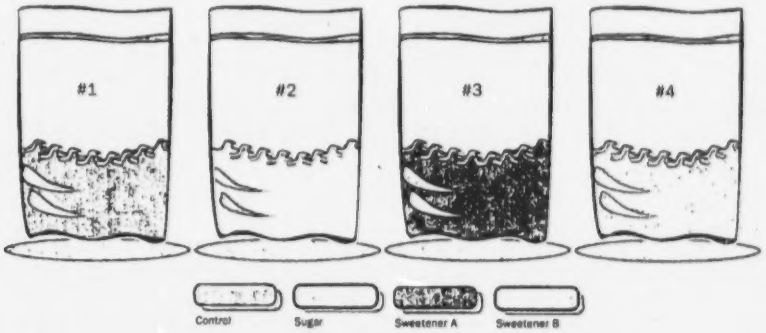


Figure 1. Possible experimental setup.

7. After 10 minutes, determine the amount of gas created in each of the bags. Record your observations. One way to measure the amount of gas produced is to measure the diameter of each bag with a ruler. Squeeze each bag to collect the gas in the bottom portion of the bag. Roll the flattened part of the bag around the bottom. Measure the diameter of each rolled bag. See Figure 2. How do the results compare to your predictions? Graph your results. Repeat the process after 20, 30, and 40 minutes. An alternate method for measuring the gas produced is water displacement. See Figure 3. Fill a 1-L container with 0.5 L of water. Measure the water level. Submerge the bags one at a time into the container of water. Mark the new level of water and remove the bag. Fill the container up to the new water level mark. Pour out 0.5 L of water, and pour the remaining amount into a 16-ounce measuring cup. Follow this procedure for each bag to measure the amount of water displaced.

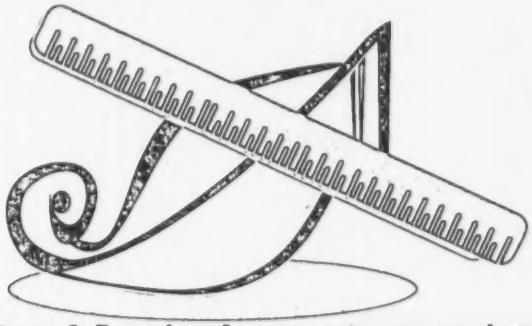


Figure 2. Procedure for measuring gas production.

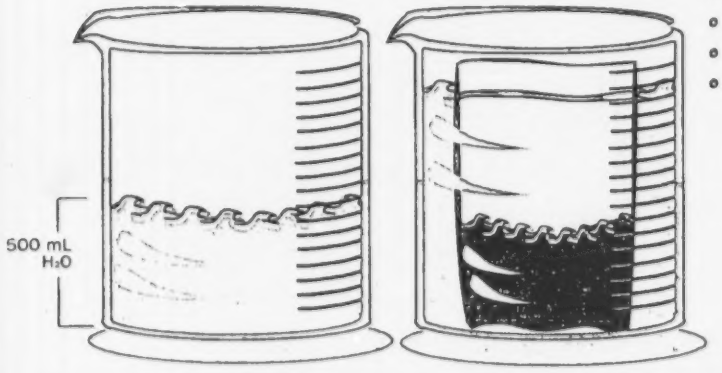


Figure 3. Measuring gas produced by water displacement.

8. Where did the gas in the bags come from? We produce carbon dioxide just like yeast. Could you design a test to prove that the gas is, in fact, carbon dioxide? How can you find out how much energy is available in different foods? How much food did the yeast in the bags use?

9. Compare the labels of the sweeteners you used. How many calories were in each? Do you see a relationship between the number of calories and the results you got?

10. How can you learn more about the chemical and energy activities of yeast? What procedures would you use? What would you measure? What if you added other ingredients? What if you changed the amounts of the ingredients? Could you design an experiment to test a new hypothesis or question?

What Did You Find Out By Doing the Activity?

Before doing "Can Microbes Tell the Difference?" did you know:

- what yeast are?
- that yeast are living?
- what living organisms need to survive?
- that living organisms produce energy from foods they eat?

From this activity, did you discover:

- how to show that yeast are living?
- how yeast are similar to humans?
- that living organisms produce energy to survive?
- how your body uses sugar?
- what your body does with things that it cannot use?
- how to measure small amounts of gas?
- which foods you eat give you energy most quickly?
- how dieting affects the body?

NATURE'S TRASH COMPACTORS

What if every plant and every animal that had died since the beginning of time still sat where it fell? Would there be any room for the living? Could the living stand the smell? Fortunately, nature takes care of things that die. Specialized organisms called "decomposers" go to work immediately to break down dead matter.

Goal

To observe microorganisms and macroorganisms that contribute to decomposition and determine factors important in decomposition.

Activity Time

1 to 2 hours for initial nature walk
1 to 2 hours to observe decaying log
30 minutes to assemble compost bags
30 minutes per week for several weeks to observe compost bags
1 hour to prepare final report of observations

Time to Get Ready

30 minutes

What You Need

Have the following for the group:

- 1 aquarium or large tub

Have the following for each team of 3 or 4:

1 hand lens
several mold, fungi, and insect guides
1 dissecting microscope, microviewer, or hand lens (optional)
5 microscope slides and cover slips (optional)
1 box colored pencils or markers
1 knife or pair of scissors
1 8-oz measuring cup
1 balance or postal scale
1 metric ruler
1 handful of grass clippings
1 handful of dead leaves, pine needles, sticks, or other organic matter
1 cup of potting soil
2 zippered, plastic bags
1 measuring teaspoon
1 pair of tweezers or forceps

Getting Ready

- Even in urban areas, participants can explore organic material that has accumulated over time by examining things like piles of leaves. Preview the area where you will take the participants to verify that it has plenty of organic material.
- If no parks or woods are nearby, collect decomposing logs or partially decomposed matter from a compost pile and conduct the entire activity indoors. The participants will need to omit Step 1 of **What To Do**.
- If participants only meet once a week, you may need to add water to the bags between meetings.
- If the group will only meet once, assemble several bags every couple of days for 2 to 3 weeks prior to the group's meeting.

Useful Information

Because not all garbage decomposes readily, many communities recycle plastic, metal, and glass to reduce wastes. But recycling is not an original concept. Nature has been doing it since the beginning of time. Specialized organisms called "decomposers" break down dead matter, reducing it to basic chemical parts. These are returned to the soil, water, and air, and supply us with carbon, hydrogen, nitrogen, and oxygen. Without it, dead matter would be piled high around us.

Composting puts the natural processes of decomposers to work turning dead plant and vegetable matter into usable soil enhancements. Within a compost pile, the decomposers come in an assortment of shapes and sizes. Chemical decomposers digest plant matter by secreting enzymes. The workhorses of the chemical decomposers are bacteria. When viewed through a powerful microscope, they appear as spheres, rods, or chains. Higher forms of bacteria called actinomycetes are responsible for the earthy smell of compost. They form long, thread-like, branched filaments that look like spider webs. Fungi are often the easiest chemical decomposers to see. They may form gray or white fuzzy colonies on the compost surface.

Many other organisms are classified as physical decomposers. They break up the particles by chewing and grinding. This activity helps the chemical decomposers do their job. Physical decomposers include mites, millipedes, centipedes, sowbugs, snails, slugs, spiders, springtails, beetles, ants, and worms.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Allow the participants to touch, smell, and describe the textures of the different organic matter, such as moist, dry, dense, and porous. This will allow for better understanding of the variable and will provide for independent hypotheses and formations of conclusions. If feasible, show the class a compost heap and allow the class to experience the "earthy" smell. Individuals who are blind have a good understanding of color and will appreciate the detailed observations.
- Construct tactile diagrams of molds, fungi, and other microbes. Show the participant the difference between a sphere, rod, and chain with objects found within the room.

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

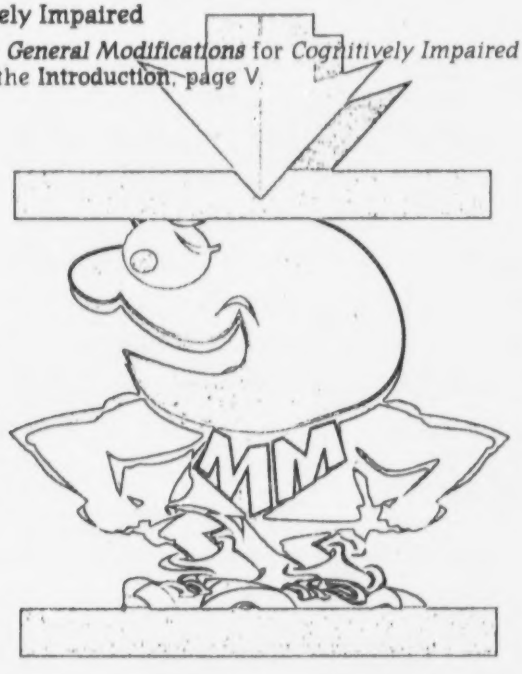
- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- See the ***General Modifications*** for *Physically Impaired* listed in the **Introduction**, page V.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.



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How to Start the Activity

Show a pile of rubbish to the participants. Ask them to imagine that there is a pile for everyone in the room, building, city. Have them discuss the problems that would occur if this rubbish did not break down.

Take the participants on a nature walk to find areas where nature is breaking down old materials in a forested area. If a walk is not possible, bring in a rotten log to examine.

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- What happens to dead materials in the woods?
- What affects how fast materials break down?
- What is needed for decomposition to occur?
- Does the presence of one material affect the breakdown of another material?

What the Data Mean

Data in this activity are qualitative. Have the participants describe the result of decomposition that they observe.

NATURE'S TRASH COMPACTORS

Questions to Think About

What would happen if everything that ever died stayed unchanged where it fell? What do you think the Earth would smell like? How deep would we be in all this? Fortunately, that doesn't happen. Soon after plants and animals die, specialized organisms known as decomposers go to work on them. These organisms are essential to compost piles. Do you know anyone who composts? Why do they do it?

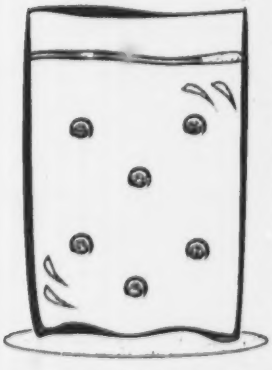
Safety Notes

- Wash hands after handling organic materials.
- Food, drinks, and gum are not allowed.
- Closed-toe shoes should be worn at all times.
- Use the knife carefully when probing the log.

What to Do

1. Take a walk in the woods or some other place where fallen branches and leaves have been on the ground for a long time. Look at the fallen trees and branches. Can you tell which ones fell most recently? Examine a fallen tree. Are all parts of the tree in the same condition? Draw pictures and describe what you see in different areas. Do you see any patterns of change on different parts of the tree or from tree to tree? Find several places where piles of leaves have accumulated. Dig through the pile and into the dirt below. Can you make a hypothesis about the conditions required for the fastest changes to occur in the leaves and the logs?

2. Take a log inside. Put it inside an aquarium or large plastic tub. Make drawings of all the different organisms you can see on the outside. Carefully take the log apart using a knife. Record all signs of living things and the changes that have occurred in the log. Use field guides to identify organisms.



3. Open 2 zippered, plastic bags. In bag #1, place a handful of grass clippings and a cup of fresh potting soil or compost and mix well. In bag #2, try a different combination of materials. For example, use whole leaves and no potting soil or crushed leaves and compost. One team could add plastic or metal. Would you expect the plastic or metal to decompose? Why or why not? Seal both bags. Use a sharp pencil to poke 6 air holes in each side of the bags. Place both bags in a warm, dark place. See Figure 1.

Figure 1. Bag with air holes.

4. Examine the bags once a week. Add a teaspoon of water each time you make observations. Record whether the grass has changed in appearance from the prior week. Estimate, measure, or weigh the changes in the volume of material. Construct a graph or chart to document your observations. What changes indicate that decomposition is taking place? Give some examples.

5. What did you learn from this activity? How does this activity relate to your life? What do you think accounts for the difference in the two compost bags? Which bag's contents decomposed faster? How do you know? Why do you think this happened? What factors do you think might influence the speed of decomposition?

6. How can you learn more about decomposition? What would happen if you repeated the experiment at different temperatures e.g., room temperature (21°C) and in a sunlit window (32°C)? What if you changed the contents of the bags? kept them in different places? exposed them to light? added compost activator or garden soil? added more or less water? Could you design an experiment to test a new hypothesis or question? What procedure would you use? What would you use as a control? What would you measure? What variables are important? How many trials would you include? Could you graph your results?

What Did You Find Out By Doing the Activity?

Before doing "Nature's Trash Compactors," did you know:

- what physically happens to organisms that die?
- why some organisms feed off other organisms?
- why organisms and humans recycle?

From this activity, did you discover:

- how organisms that feed off dead matter help the environment?
- how recycling by humans relates to organisms in nature?
- what would happen if dead animals were left to sit forever?
- what factors affect how quickly dead matter can be broken down?
- what you can do to increase recycling in your area?
- why using a garbage disposal for leftover food can help the environment?
- what organisms feed off dead plant and animal matter?

NOW YOU SEE IT, NOW YOU DON'T

What happens to biodegradable products? Do they really just disappear, or do they break down into different things? What causes them to break down in the first place?

Goal

To investigate the process by which commercial packing peanuts biodegrade.

Activity Time

5 days

Time to Get Ready

20 minutes one day before

What You Need

Have the following for each team of 2:

6 clear plastic or glass jars (minimum 1 cup capacity)
1 measuring cup
eye droppers
7 biodegradable packing "peanuts" made of starch
7 packing "peanuts" made of plastic
iodine tincture solution (drugstore antiseptic version)
distilled or tap water
compost additive
corn starch or flour
1 potato slice
1 measuring teaspoon
test tube
1 coffee stirrer or plastic spoon
1 large bottle, cup, or bucket for waste liquids

Getting Ready

- Collect at least 2 varieties of packing peanuts. Verify that 1 type dissolves in water and the other does not.
- Use fresh iodine tincture that contains iodine and iodide salts. Decolorized iodine antiseptic may not work since it only contains iodide salts.
- Check that the water source does not contain chlorine that will interfere with the iodine test for starch. Mix 1/4 cup of water with 1 teaspoon of corn starch. Add a drop of brown-colored iodine to the starch solution. You should obtain a blue-black color when starch and iodine mix. If no reaction occurs, fill containers with tap water and let them sit overnight so the chlorine dissipates before the water is used.
- Purchase compost activator at a garden supply store or from a gardening catalog. Read the label on the compost additive/activator, and make sure that it contains live microorganisms and not just extra nutrients as some brands do.
- If the group will not be meeting over an extended period of time, make up sets of jars each day for 1 week before the group meets. They can test each set and see how changes occur over time.

Useful Information

Some packing materials are made of biodegradable substances. Because most are made of starch, water dissolves them. But for them to be broken down completely, the process depends on the many microorganisms commonly found in the soil. The microorganisms secrete a digestive enzyme that degrades the starch into its simple sugar building blocks. These simple sugars, or building blocks, can be used as energy sources by microorganisms. This is similar to what happens when a human eats starch. A digestive enzyme in saliva called "amylase" breaks down the starch into simple sugars. See Figure 1.

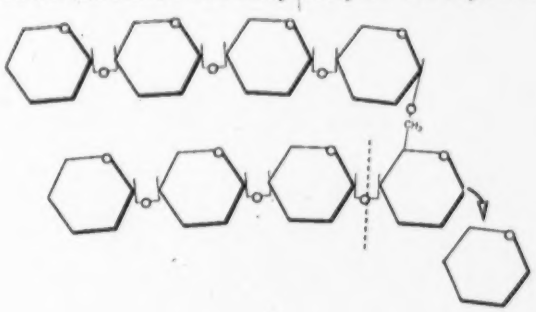


Figure 1. Diagram of a starch molecule with one unit of sugar removed.

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Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Encourage the participants to touch and describe any tactile differences in the packing peanuts. Squeezing and crunching the packing peanuts may help the participant to understand the possible variables and to develop independent hypotheses and conclusions.
- Emphasize group discussions and the importance of making specific observations. Refer often to color, texture, size, and moisture. Individuals who are blind have a good understanding of color and will appreciate the detailed observations.
- Construct a tactile model of a starch molecule if one is not available. See the materials suggested in the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

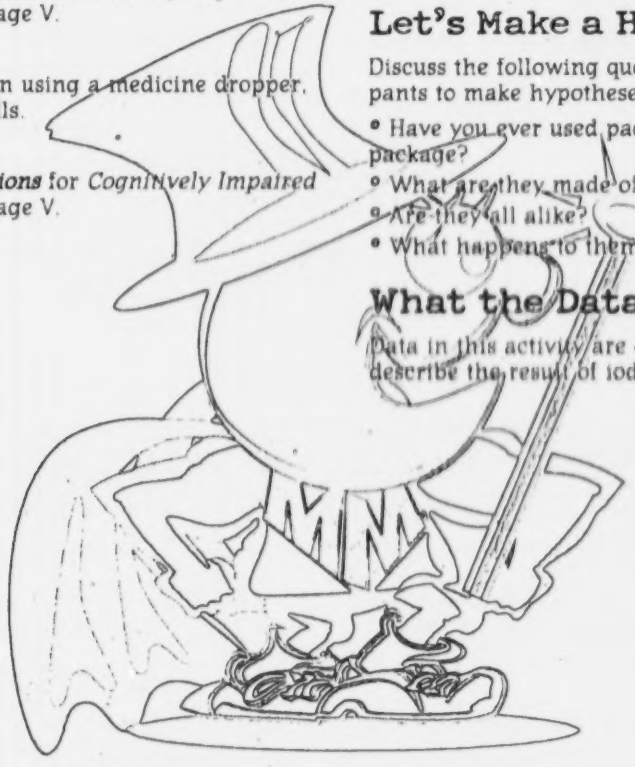
- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- Emphasize teamwork when using a medicine dropper, as it requires fine motor skills.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.



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How to Start the Activity

- Show students the packing peanuts and ask what they think the packing material is made of. Place a plastic peanut in 1 glass of water, and a starch peanut in another. Observe the results.
- An iodine test is often used to confirm the presence of starch in a sample. When iodine is added to a starch solution, the resulting blue-black color is caused by a reaction between the starch and iodine. Repeat the iodine test with a sugar solution. This will remain a yellowish-brown color. Sugar does not react with iodine.

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- Have you ever used packing peanuts for filler in a package?
- What are they made of?
- Are they all alike?
- What happens to them when they reach the landfill?

What the Data Mean

Data in this activity are qualitative. Have the participants describe the result of iodine tests that they observe.

NOW YOU SEE IT, NOW YOU DON'T

Questions to Think About

Mom, the family pack rat, stores old, empty boxes down in the basement to have a supply on hand just in case she needs to send packages to Grandma. One day, the washing machine overflowed, soaking the boxes. To her amazement, Mom found that the packing peanuts in one box had "melted away" while those in the other boxes were wet, but intact. What happened? Can you test packing peanuts to see if you can determine a difference?

Safety Notes

- Wash hands before and after the activity.
- No eating or drinking during the activity.
- Avoid getting iodine on skin or clothing.

What to Do

1. Lay a potato slice out on your table. Put drops of iodine at 4 separate locations on the slice. What happened? The resulting blue-black color is caused by a reaction between the starch in the potato and the iodine. An iodine test like this is often used to confirm the presence of starch in a sample.

2. Put a drop of iodine on a polystyrene and a biodegradable packing peanut. What happened? Is the result similar to the reaction you got when you put the iodine on the potato? What does this tell you about the makeup of the packing peanuts?

3. Label your jars 1 through 6. Put 1/4 cup or 50 mL of water in each. Put 1 teaspoon of corn starch in jars 1 and 2. Put 2 biodegradable peanuts in jars 3 and 4, and 2 polystyrene peanuts in jars 5 and 6. Add 1 teaspoon of compost activator to jars 2, 4, and 6. Mix the contents in each jar. See Figure 1.

4. Test the contents from each of your jars for starch. Put 5 drops of the solution from the first jar in a test tube. Add a drop of iodine to the solution. Record your results. Rinse your test tube thoroughly before testing the contents from the next jar.

5. Each day retest the contents from your jars for starch. Record your results. How long does it take for you to see a change?

6. Do your results and conclusions lead to other questions? What did you learn from this activity? How does this activity relate to your everyday life?

7. What would happen if you buried a starch peanut and a polystyrene peanut in the soil during the fall, and then dug them up in the spring? Does temperature have an effect on the rate of starch breakdown? Does the amount of bacteria or starch affect the rate of starch breakdown? Are live bacteria necessary for breakdown action? Could you design an experiment to test a new hypothesis or question?

8. Design a new experiment based on data you gathered or questions you asked during this investigation. Develop a hypothesis that can be tested in a controlled experiment that gathers data. Write a procedure in a numbered list to test your hypothesis. What is your control? What variables are important? How many trials have you included? What will you measure? How can you show your results in a graph?

What Did You Find Out By Doing the Activity?

Before doing "Now You See It, Now You Don't," did you know:

- that some packaging "peanuts" can be eaten?
- any substances that can be broken down into simpler parts in nature?

From this activity, did you discover:

- how substances are broken down in nature?
- why things that are able to break down into their basic parts are good for the environment?
- how microbes play a role in breaking down substances in nature?
- what happens to substances once they are broken down in nature?
- any frequently used products that can be made so that they break down easily in nature?

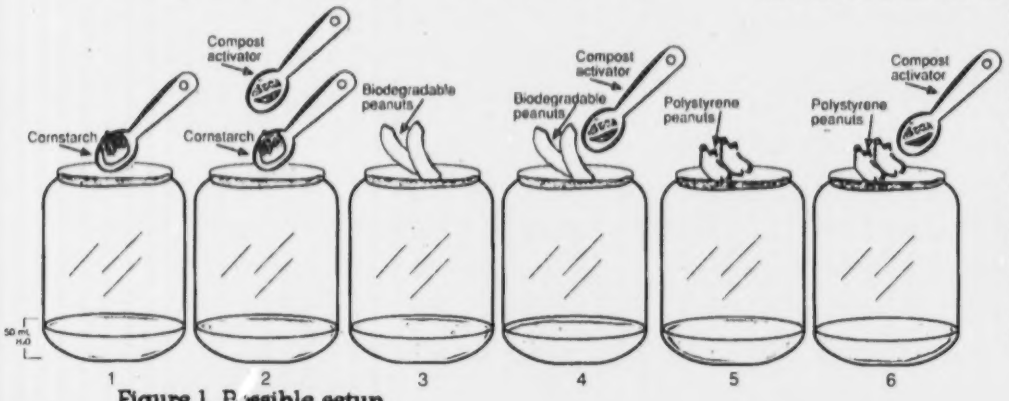

Figure 1. Possible setup.

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CAUGHT RED-HANDED

When was the last time you washed your hands? Did you use soap? How long did it take you? What have you done since you washed? Have you eaten? Touched your face? Touched someone else?

Goal

To evaluate the effectiveness of different handwashing times, techniques, and materials in reducing the number of microbes.

Activity Time

50 minutes

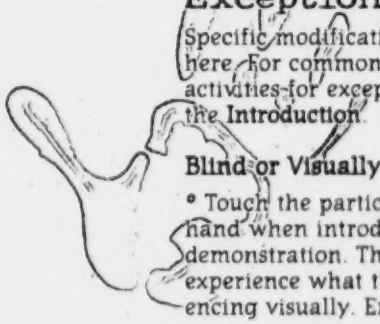
Time to Get Ready

15 minutes

What You Need

Have the following for each team of 3 or 4:

1 apron or smock
1 timer
sink with running water or bucket of water
1 opaque shield or blindfold
30 mL washable paint or glitter
paper or fabric towels
hand cleansing agents
hot running water (optional)
2 cookies (for demonstration)
old newspaper



Getting Ready

- If a sink is not readily available in the room, fill a bucket of water for each group.
- Obtain 2 cookies and 5 mL of washable paint for pre-lab demonstration.
- Dirty the palm of one hand conspicuously with the washable paint just before the group meets. Glitter may be used in place of paint.

Useful Information

A survey was taken of scientists at an infectious disease meeting. The results were pretty scary. Only 80 percent of these learned women and 60 percent of the men washed their hands after using the restroom. Yet, thorough handwashing is one of the best ways to reduce microbes and prevent infections. The human body naturally carries an abundant supply of microbes. The resident microbes, which are usually harmless, establish a miniature ecosystem with the body to maintain health. But these microbes are very sensitive to certain factors. An upset in their balance can allow them to be replaced by more transient microbes which may be harmful. Handwashing with plain soaps suspends the microbes and allows them to be rinsed off. Antibacterial soaps inhibit the growth of microbes.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the Introduction.

Blind or Visually Impaired

- Touch the participant with the "soiled" (painted) hand when introducing the activity and during the demonstration. This will enable the participant to experience what the other participants are experiencing visually. Emphasize the coughing, too!
- Advise participants to provide specific observations. Glitter or glitter mixed with colored paint is an excellent alternative to the colored paint. Glitter provides the participant with the ability to feel how dirty his/her hands are.

• Allow participants to shade in and color cardboard cutouts of hand shapes. The cutouts will provide the participant tactile boundaries when coloring. Have the participant use crayons to make a waxy film. More wax represents more dirt. A hole punch can mark how well each hand is cleaned. For example, use one punched hole to represent one "+."

Deaf or Hard-of-Hearing

• See *the General Modifications* for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

• Wrap any exposed pipe underneath the sink area if it is not already protected. Running hot water while washing hands may be a safety concern for a participant in a wheelchair. A participant with paralysis in the lower extremities will not be aware that his/her legs are against the hot pipes.

Physically Impaired

• Offer crayons that are flat on one side and larger in size to allow the participant more control when coloring. The crayons will not roll off the table. If necessary, provide participants with assistance when tracing their hands.

Cognitively Impaired

• See the *General Modifications* for *Cognitively Impaired* listed in the **Introduction**, page V.

For More Information

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How to Start the Activity

In front of the participants, simulate a cough into your apparently clean hand that has not been "painted." Pick up identical cookies in each hand and hold them out to the participants. As you do, expose both palms to the participants. Ask them which cookie they would like to eat. They ought to reject both choices as unacceptable. A reasonable hypothesis would be that both the apparently clean and obviously dirty hands have unseen microbes on their surfaces. These microbes may or may not be harmful. Confirming both the microbes' presence and type would require growing a culture. (See "Fun with Fomites" activity.)

Let's Make a Hypothesis

Ask the following questions to help guide the participants to hypothesis formation.

• What have you handled since you last washed your hands?

• How long does it take to adequately wash your hands?

• Does it matter whether the water is hot or cold?

• Is one soap as good as another?

• How can you find the answers to these questions?

What the Data Mean

	washing time (seconds)			
washer	0	1	5	20
1.	++++	+++	++	+
2.	++++	+++	+	+
3.	++++	+++	++	+
average	++++	+++	++	+

KEY: Surface Area w/Paint ++++ 100% +++ 75% ++ 50% + 25%

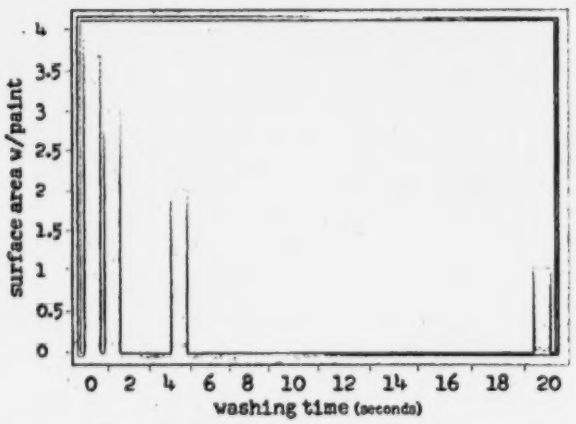
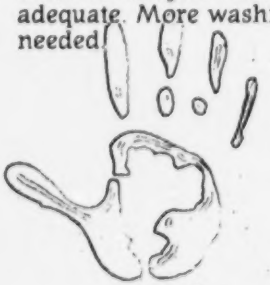


Figure 1. How washing time affects cleaning your hands. Washing longer does appear to be better, but even the longest washing time attempted was not adequate. More washing time or use of a cleanser is needed.



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CAUGHT RED-HANDED

Questions to Think About

Your dentist has probably told you that an adequate tooth brushing job will take two minutes. The dentist also has given you careful instructions about how to brush. If you follow those instructions every time you brush your teeth, and you brush frequently, you probably have healthy teeth. What do you think the important elements are to washing hands?

Safety Notes

- Food, drinks, and gum are not allowed.
- Use water that is not so hot that it can scald.
- Wear a smock or apron while working with paint.
- Do not touch your face with glitter or paint

What to Do

1. Your group will determine how the length of time spent washing hands affects their cleanliness. You will do this by simulating the removal of microbes from your hands. Instead of using actual microbes, though, you will use either paint or glitter. As a group, devise a scheme for scoring hand cleanliness. Divide a piece of paper into 4 sections. Trace a hand outline in each section of the paper. Then use pencils, crayons, or paint to shade in your idea of a completely dirty, very dirty, dirty, and somewhat dirty hand. Some parts may be darkly shaded, and some parts lightly shaded. Label the completely dirty hand as ••••, the very dirty hand as •••, and so on.

2. Cover your work space with old newspapers. Designate 1 member of the group as the hand washer and 1 as the timer. As the washer, put about 5 mL of washable paint in the palm of one hand and spread it, like lotion, as evenly as you can over all the skin of your hands, even the skin next to your fingernails. Without touching anything, allow your hands to dry completely. This will take only a minute or two. If you are using glitter, pour it on a piece of paper and then press your hands into the glitter until they are well covered. Put the paint or glitter away.

3. At the sink, 2 team members hold a shield over the sink so the washer cannot see his/her hands. Have the washer wash for 1 second. After the washing, have the timer blot the washer's hands without letting him/her see them or giving any information about the hands' cleanliness. Using the scoring scheme, record the cleanliness.

4. Have the washer wash for an additional 4 seconds. Have the timer blot the washer's hands and record their cleanliness. Allow the washer to wash for 15 more seconds. Once again, have the timer blot the washer's hands and record their cleanliness.

5. Allow the washer to completely clean his/her hands. Then repeat steps 2 to 4, only this time, permit the washer to use any available cleaning agent. Change roles and repeat the exercise until you have at least three sets of data. As much as possible, have the same person time the washings and record the cleanliness.

6. Analyze and display the results by creating a graph using the average result at each time interval. In graphing the results, remember to put the element that is changed on the x-, or horizontal, axis. Be certain to leave a space for every number between 0 and the final time, not just one space for each time measured. Put the evaluation of cleanliness on the vertical axis. Can you predict what would happen if you increased the washing time or modified the technique by rubbing more vigorously?

7. What, if any, errors might have been introduced into the experiment? Why was it important to have the same person score all the hands? What infectious diseases might be transmitted by failure to adequately wash your hands? Are your observations likely to change your behavior or impact the health of your family? How?

8. Design a new experiment based on data you gathered or questions you asked during this investigation. What is the question you are investigating? What hypothesis could you propose? What procedures would you use to test this? What variables are important? What is your control? How many trials have you included? What will you measure? How can you show your results in graphs?

What Did You Find Out By Doing the Activity?

Before doing "Caught Red-Handed," did you know:

- why you wash your hands before meals?
- why you use soap when you wash your hands?
- how touching things affects how clean your hands are?
- why the temperature of the water is a factor when washing hands?
- if you could see the microbes that exist on your hands?
- how long you should wash your hands each time?

From this activity, did you discover:

- how hand washing affects microbes?
- how different microbes affect the human body?
- why harmful microbes make you sick when they get into your mouth?
- how antibacterial and plain soaps differ in their effects on microbes?
- how much time is needed for effective handwashing?
- how your handwashing habits may change after doing this activity?
- if the microbes on your hands can have a serious effect on your personal health?

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DEFEND YOUR SURFACE

Boat owners constantly fight a battle with microbes that settle on the bottoms of their boats. Any boat, float, or pier that stays in the water more than 24 hours is soon covered with a slime layer of bacteria. After that, even larger organisms find the surface a suitable home.

Goal

To design and test a surface that prevents harmless microbes from sticking to it.

Activity Time

Two 90-minute sessions

Time to Get Ready

90 minutes

What You Need

Have the following for the entire group:

4 clear, empty 2-L soda bottles
1 pair of scissors
1 hole punch

Have the following for the entire group only if using a small natural body of quiet water:

4 empty, washed liquid laundry detergent bottles with lids
4 lengths of rope or cord 30 cm longer than the water is deep
4 medium-sized rocks or similar weights

Have the following for the entire group only if using an artificial pond:

4 buckets at least 40 cm tall
4 sticks or dowels at least 25 cm long

Have the following for each group of 3 or 4:

surface coating material such as petroleum jelly, nail polish, hot pepper sauce
2 medium-sized washers, fishing weights, or small stones
1 magnifying glass
1 bucket, pan, or bowl
2 1-meter (m) lengths of string
5 pieces cut from soda bottles, pennies or pieces of aluminum foil or wood
1 stereoscope or microscope

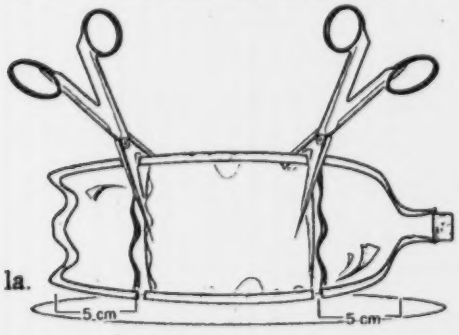
Getting Ready

Two weeks before

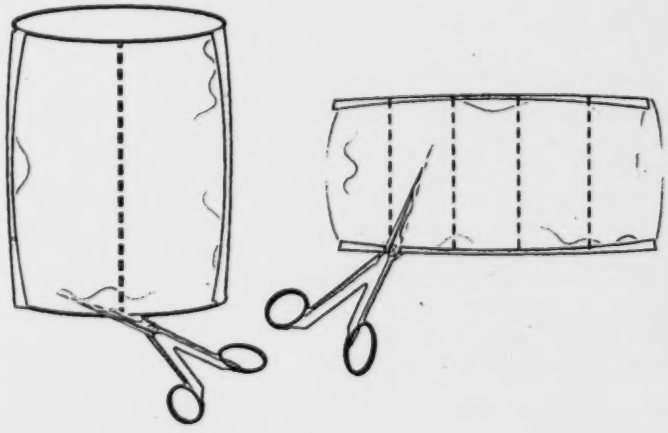
- Locate a quiet body of water at least 25 centimeters (cm) deep. Good sites include small ponds or lakes, quiet saltwater harbors or estuaries, quiet areas of streams, or drainage ditches with water in them. Be sure to obtain permission from the landowner if the water source lacks public access. Determine the depth of the water.
- If no natural water source is available, an artificial pond can be created. Two weeks before, obtain a bucket 30 to 40 cm deep. Fill it with water and let it sit at room temperature for 24 hours. After 24 hours, pour 2 cups of dirt or mud into the bucket. Make sure that the mud is as free of chemicals as possible.

One day before the activity

- Cut the top and bottom off soda bottles 5 cm from each extreme. See Figure 1a. The tops and bottoms can be discarded. Cut the remaining portion in half from top to bottom. Flatten the portion and then cut them into 5-cm x 15-cm strips. Cut 5 strips for each group. See Figure 1b. Punch a hole in each end of the strips cut from the soda bottle. See Figure 2.



1a.



1b.

Figure 1a. Cut the top and bottom off the bottle. 1b. Preparation of strips.

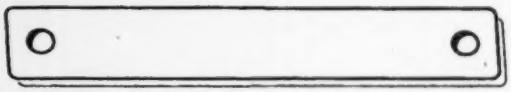


Figure 2. Hole placement for each strip.

- Cut 2 1-m lengths of string for each group.
- If the group's time will be limited, or you are working with younger students, you may want to assemble the ladders ahead of time.
- If you will be using a natural body of water, prepare floats by thoroughly washing 4 laundry detergent bottles and tightening the lids. Cut a piece of rope 30 cm longer than the water is deep for each bottle. Tie one end of the rope to the handle of the bottle. Tie the other end of the rope to a rock or weight. Repeat the process for each of the laundry bottles. See Figure 3.

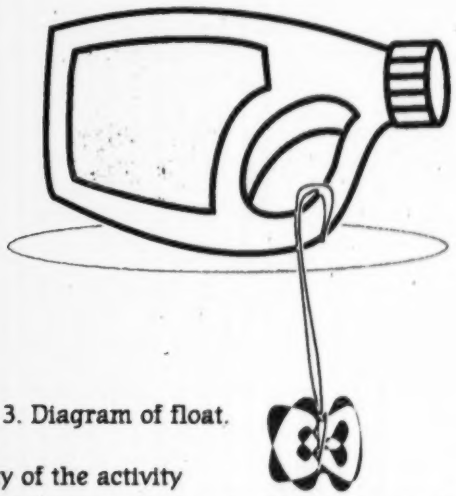


Figure 3. Diagram of float.

The day of the activity

- Lay out the materials required for each group's work in their separate areas. Each group should have 5 prepared pieces of soda bottle or other material; 2 1-m lengths of string; 2 washers, weights, or stones; and access to surface coating materials.

The second day of the activity

- Provide each group with a bucket, pan, or bowl and a magnifying glass.

Useful Information

All microbes need a place to live where they can be safe and find food. Most have developed ways to adhere, or stick, to the surfaces where they live. Adherence is a very important part of how some microbes live. Without being able to stick to a surface, they could not get food, or survive.

Frequently, microbes stick to surfaces in great numbers creating a coating known as a "biofilm." Sometimes, a biofilm can be very helpful. The rocks and decorations in both salt- and freshwater aquaria are usually covered with a biofilm of useful microbes. The microbes help convert ammonia and nitrates from waste products into less toxic substances. On the other hand, some biofilms are harmful. That slick feeling you get on your teeth when they need to be brushed is caused by a biofilm of microbes that have attached themselves since your last brushing. If allowed to remain, they contribute to cavities.

The biofilm that builds up on the bottom of pools is sedentary protozoa and algae. The submerged surfaces of marine docks, floats, and boats support a variety of organisms. Growth of organisms on surfaces, called "fouling," can cause problems. Marine fouling on the bottoms of ships reduces the speed of the vessel and causes an increase in fuel consumption. In the Great Lakes, industrial and municipal pipelines become clogged with zebra mussel colonies.

Over the years, many products have been introduced to try to inhibit fouling. Municipalities use chlorine to control zebra mussels. Fungicides and algaecides are used to control soft fouling organisms. Many boat owners coat the bottoms of their boats with paints to keep these organisms from growing. Often the paints are very toxic and dangerous both for the people applying the paint and for the environment. However, some bottom paints currently being manufactured contain extracts of hot peppers that may be safer.

If you use a freshwater body of water in your experiment, you will see protozoa. These are tiny, one-celled animals that are too small to be seen individually. See Figure 4. They are often sedentary, or live stuck to one surface and don't move around. Most are very important in breaking down dead plants and animals. Some eat bacteria and other protozoa. Others filter the water around them for food. If you use a saltwater body of water in your experiment, you will see tiny versions of marine "float animals." These organisms live underwater on mooring floats and pilings of docks and wharves. They include barnacles, bryozoans, tiny corals, sea squirts, and sea anemones. Some look like brown and red seaweed, but are actually animals. See Figure 5.

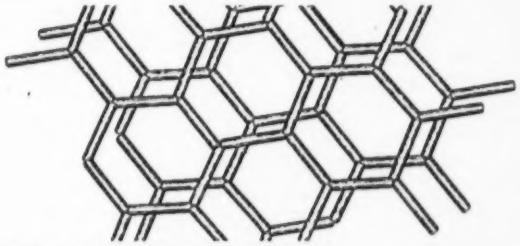


Figure 4. Freshwater protozoa.

Figure 5. Marine organisms.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Allow the participant to feel the difference between the coatings used for the activity. Comparing the petroleum jelly and the hot pepper sauce will reinforce the concept. Exercise care that the participant does not rub his/her eyes accidentally and that hands are washed after this step.
- Use cubed manipulatives to construct a bar graph that shows the growth progression of a biofilm.
- Build a tactile model of a protozoa if one is not available.
- Allow the participant to touch the slime.

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the Introduction, page V.

Mobility Impaired

- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- See the ***General Modifications*** for *Physically Impaired* listed in the **Introduction**, page V.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

For More Information

ADHA. Oral health FAQs *http://www.adha.org/blip/blip-faqs.html*. An American Dental Hygienists Association site that includes information on oral health, including a fact list and news briefs.

Jensen, M.N. (1998). Good health requires good gums. *Science News, 153*(19), 300-301.

Jones, M., et al. (1997). *Biofilms: Community Interactions and Control*. (Biofilm Club Publications.)

Lee, J. (1998). Bacterial biofilms less likely on electropolished steel. *Agricultural Research, 46*(2), 10-11.

Patients take notice of caries vaccine. *http://www.ada.org/adapco/daily/archives/9805/0505vacc.html*
An American Dental Association site that includes daily news articles in dentistry in addition to an archive of recent articles.

Scientists develop vaccine against tooth decay. *http://www.ada.org/prac/position/vaccine.html*. An American Dental Association site that includes daily news articles on technological breakthroughs in dentistry.

Teaching tools. Lesson plans. *http://www.oralb.com/teaching/lesson/9_12/dayl.html*. This commercial site is a source of information on Oral-B. The site includes a section of teaching tools comprised of lesson plans on the importance of oral care for educators at various levels.

Tooth decay. Health library. *http://www.thriveonline.com/health/Library/illsymp/illness529.html*. A site that focuses on tooth decay: General information, what to expect, and how to treat.

Wu, C. (1997). Material gives bacterial films the heave-ho. *Science News, 151*(17), 253.

How to Start the Activity

Show the participants a jar of water collected from a pond or relatively clean ditch. Have them hold the jar up to the light and look for tiny organisms swimming in the water. Discuss the organisms. Explore the possibility that similar organisms are found in other bodies of water. Discuss what organisms need to live.

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- What kind of surface would be suitable for microbes to live on?
- What substances might inhibit the adherence of microbes?
- How can you test your hypothesis?

What the Data Mean

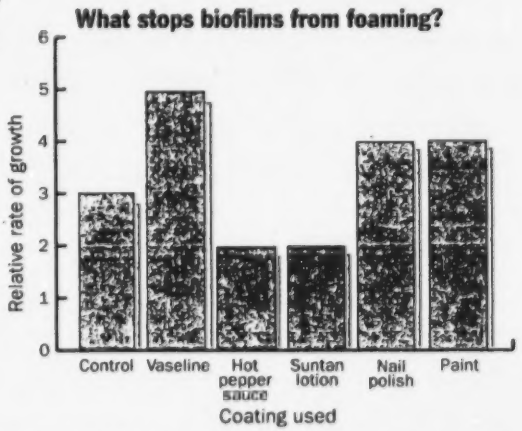


Figure 6. Sample graph of substances used to stop the formation of biofilms.

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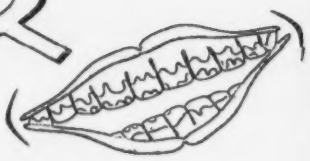
DEFEND YOUR SURFACE



Questions to Think About

How can microbes make you sick? When you sneeze or cough into your hand, why don't the microbes just fall off? Run your tongue over your teeth. What do you feel? Are there microbes on your teeth? If you look into a pool, you may see a green coating on the sides and bottom. These are biofilms made up of microbes. Do microbes stick better to some surfaces than others? Can you coat a surface with something to prevent microbes from sticking to it? Can you coat a surface to encourage microbes to stick to it? How can you find answers to these questions?

Safety Notes

- Wash hands before and after the activity.
- Make sure that all materials collected for surface coating are safe to handle.
- Food, drinks, and gum are not allowed.
- Life jackets should be worn by participants working near natural bodies of water.
- Care should be taken with scissors and hole punches.
- Avoid getting hot sauce on hands or in eyes.
- Closed-toe shoes should be worn at all times.

What to Do

Day 1 of the activity

1. Arrange your 5 soda bottle pieces in a row so that the long sides are parallel. Thread a piece of string through the hole in the end of one of the pieces. Leave 7 cm hanging, then tie the string to the piece. Thread the next bottle piece onto the string and tie it off 3 cm from the first. See Figure 1 for 2 strips that have been tied together. Continue to thread the bottle pieces onto the string and tie each piece 3 cm from the last. Repeat the process on the other side. When all the bottle pieces are threaded onto the strings, it should resemble a ladder. Tie washers, weights, or small pebbles to each of the 7-cm pieces of string hanging from the bottom. Tie the top pieces of string together as shown in Figure 2.

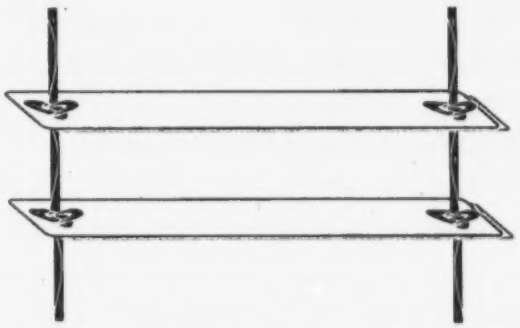


Figure 1. Shown are 2 of the 5 strips that have been tied together.

2. Leave the top rung of the ladder uncoated. It will serve as your control. Coat the remaining rungs with surface coating materials. Use a different coating substance for each rung. Be sure to coat both sides of the rungs. Make note of which substances are used on which rungs.

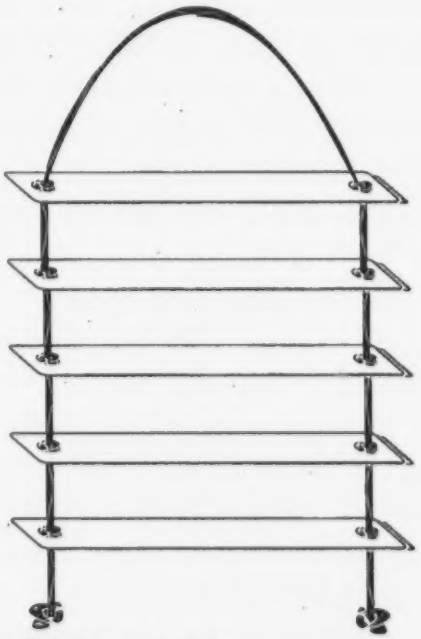


Figure 2. Diagram of setup.

3. If you are using a natural body of water for your experiment, place a float near enough to the shore for easy access, but far enough from shore so the ladders will hang without touching the bottom. Tie your ladder to a float. If several groups share a single float, try to arrange the ladders so they touch each other as little as possible. Leave the floats and ladders undisturbed in the water for 2 weeks.

4. If you are using an artificial pond, place a stick or dowel across the top of the bucket. Tie the ladders to the dowel. Try to position ladders so they touch each other as little as possible. Leave the ladders undisturbed for 2 weeks.

Day 2 of the activity

5. Fill a bucket or pan with water from the experiment site. Collect your ladder. Place it in the bucket or pan so it doesn't dry out.

6. Examine the surfaces of your ladder with a magnifying glass. Your microbes may look like green, brown, red, or pink spots. Rate the amount of growth on each rung on a scale of 1 to 5. Give the control a rating of 3.

7. Rungs with more growth should be rated 4, while those with much more growth should be rated 7. Rungs with less growth should be rated 2, and those with much less growth should be rated 1. Construct a bar graph that compares the data. The type of surface coating should be entered on the horizontal axis, and the growth rating should be entered on the vertical axis.

8. What other questions come from your results? To what other topics is this activity related? How does this activity relate to your life?

9. How can you learn more about microbe adhesion? Would the microbes' ability to adhere be the same on different surfaces? Is it the same in all temperatures? Could you design an experiment to test a new hypothesis or question? What procedures would you use? What would you use for a control? What variables are important? What would you measure? How many trials would you include? Could you graph the results?

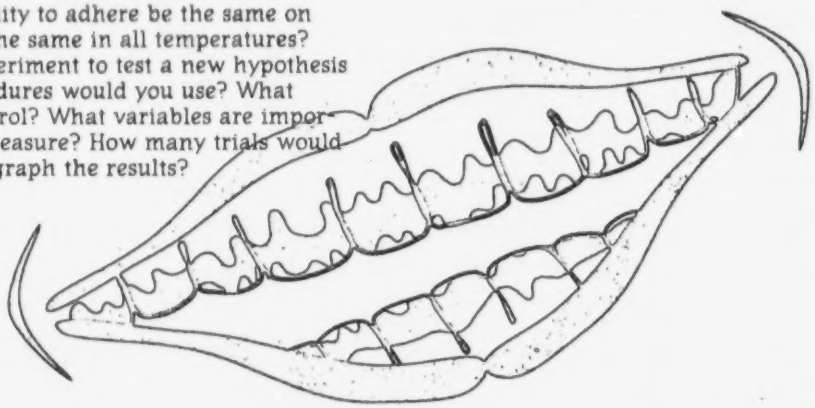
What Did You Find Out By Doing the Activity?

Before doing "Defend Your Surface," did you know:

- if you had ever seen slime on a surface?
- if a slime layer is living?
- what the slime is that grows on boat bottoms?
- if there is a way to prevent a slime layer from growing?
- other places that slime appears?
- what slime needs to grow?
- if slime occurs in all water areas, such as pools and sinks?

From this activity, did you discover:

- how slime grows on boat bottoms?
- how slime growth can be prevented?
- why slime doesn't grow on surfaces in swimming pools?
- how the slime on boat bottoms is like the slime that can cover your teeth?
- why slime only grows on the bottom of the boat?
- if your individual tooth-brushing habits should change to reduce the chance of slime?
- if brushing is the only thing you need to do to prevent a slime layer from covering your teeth?



LET'S GET SMALL

How small is a microbe? Is a virus smaller than a protozoan? Is it bigger than the diameter of a human hair?

Goal

To develop an understanding of the comparative sizes of microbial life, including viruses, protozoa, bacteria, and very small parts of the human body.

Activity Time

50 minutes

Time to Get Ready

15 minutes

What You Need

Have the following for each team of 2 or 3:

1 meter stick or ruler
1 measuring wheel (optional)
1 box sidewalk chalk
1 Microbe Reference Chart
1 magnifying glass

Getting Ready

- Arrange to use a large area like a parking lot, gymnasium, or sidewalk. Bigger is better for this activity. Several of the participants' measurements may not fit in the space available. They will still be able to compare the size differences.
- Measure off a section that is 100 meters (m) long to represent the width of a piece of human hair.
- Have each group draw a different microbe from the Microbe Reference Chart on page 47.

Useful Information

Many different microbes live all around us and even in us! The smallest of these are viruses, bacteria, and protozoa. Viruses are the smallest of all microbes and hardly can be seen with even the strongest and most expensive microscopes. Because they are so small, they cannot be measured using our usual scales for measurement. Scientists use a different scale to describe the size of microbes. Viruses are measured in nanometers, which are one million times smaller than a millimeter (0.000001 millimeter). Viruses cause the most familiar diseases such as chicken pox, warts, and AIDS. But they also have other roles. Tulips would be dull without them. The white stripes on the petals of many tulip varieties are caused by infection with viruses. Much of our biotechnology, including the development of vaccines and drugs, could not take place without the ability of viruses to transfer genetic information from one organism to another.

Figure 1. Spoon of bacteria (not to scale).

Bacteria are bigger than viruses, although they are still very small. They are found almost everywhere. We find them in the freezing cold of Antarctica and in boiling hot springs. Bacteria also live around and even in us. They are so small that one spoonful of soil contains more than one hundred million bacteria!

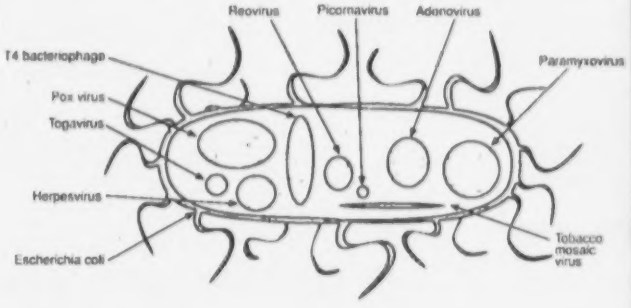


Figure 2. Size comparison of microrganisms.

Most bacteria are measured in micrometers, which are one thousand times smaller than a millimeter (0.001 millimeter). See Figure 2. Bacteria cause many diseases such as strep throat, tuberculosis, sexually transmitted diseases, and food poisoning. However, we could not live without them. They convert energy from the sun into forms we can use. All the bacteria in your body would fill a soup can. Almost all of them are found in your digestive system and on your skin. Among their most important tasks is making several vitamins that you need to survive, as well as helping you digest food.

Most protozoa are also microscopic, but a few can actually be seen without a microscope. Most protozoa move around very easily. Some have hundreds of tiny leg-like parts. Some protozoa eat bacteria, and some make their own food using the sun's energy. They live all around us, and we depend on them for many things. Some keep cows alive by changing dry hay into food they can use. Other protozoa cause some of the more common diseases found in the tropics such as amoebic dysentery, malaria, and *Giardia*.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Use a large space, such as a gymnasium, for this group activity. Mark the 100-meter distance with bright textured tape. If the participant has any residual sight, the bright color of the tape will contrast with the color of the floor. The participant will be able to feel along the length of the measured area. This will provide the participant an understanding of the length and enable him/her to relate to the discussions of "size."
- Refer to the discussions that are outlined in **Useful Information** and **Introducing the Activity**. They are excellent in developing a comprehension of the material and purpose.
- Construct a tactile diagram of a microbe to provide the participant with an understanding of the language references to "microbe." Detailed descriptions of each microbe will be useful.
- Have the participant relate the size of the microbe to a cup, bowl, or basket as an alternative to the one suggested in the activity.

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

- Use a floor that is smooth and with a lot of room to maneuver in and around, such as a gymnasium.

Physically Impaired

- Use a floor that is smooth and with a lot of room to maneuver in and around, such as a gymnasium. Set up some seating prior to the meeting time to allow participants to be seated while group discussions occur.
- Offer crayons that are flat on one side and larger in size to allow the participant more control when coloring. The crayons will not roll off the table.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

For More Information

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Pelczar, M.J., Chan, E.C.S & Krieg, N.R. (1993). *Microbiology: Concepts and Applications*. New York: McGraw Hill Inc.

Rainis, K.G. & Russell, B.J. (1996). *Guide to Microlife*. Danbury, CT: Grolier Publishing.

Ruppert, E.E. & Barnes, R.D. (1994). *Invertebrate Zoology*. Fort Worth, TX: Saunders College Publishing.

Trimble, J.M. (1991). Classroom debate: Are viruses living organisms? *Favorite Labs from Outstanding Teachers, Volume I*. Reston, VA: NABT Publications, 20-23.

How to Start the Activity

- Discuss the use of models with the participants. Models are often used in science to compare and study subjects that are difficult to see.
- Explain that sometimes models are larger than the real item and sometimes they are smaller. Remind them of models they are familiar with such as model cars, planes, and game pieces. Explain that these models help us when the real item is very large. Other models, especially those used by scientists, are used when the real item is very small.
- Discuss different units of measurement.
- Have participants pull a single piece of hair and hold it between their thumb and index finger. Explain that the space between their thumb and finger is the width of a piece of hair. Be sure they understand the difference between the width and length of the piece of hair.

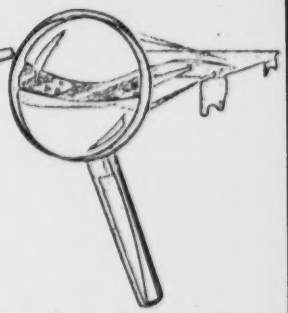
Let's Make a Hypothesis

This activity does not lend itself to making hypotheses.

What the Data Mean

There are no data for this activity.

LET'S GET SMALL



Questions to Think About

While diseases caused by microbes are very important, are there more microbes that actually help us? Yes! Oceanic plankton are microscopic plants and animals that form the beginning of the food chain in the ocean. Many produce the very oxygen we breathe. Pond water is also full of such organisms. Lichens and corals depend on microscopic algae to live. The white stripes on many tulip petals are caused by a virus that infects the plant. People could not survive without intestinal bacteria creating essential vitamins and helping digest food. We would not have cheese, wine, or antibiotics without microbes. However, can you see organisms as small as bacteria and viruses? Why are models often used to study and compare very small subjects? In this activity, you will use a model to help you "see" the size of viruses and bacteria.

Safety Notes

- No running or playing with the equipment.
- Food, drinks, and gum are not allowed.
- Wash hands at the end of the activity.

What to Do

1. Take the piece of hair you looked at earlier and examine it with the magnifying glass. Does it look larger when you look at it under the glass? Examine a piece of hair from another participant with the magnifying glass. Compare its thickness, or width, to your own hair. If you were going to make a model of a piece of human hair, would you make it larger or smaller than a real piece of hair? Do you think microbes are smaller than the width of a piece of hair? If you needed to make a model of a microbe, would you make it larger or smaller than the original?

2. Lay your meter stick or ruler out in front of you. What kinds of things do you measure in meters? Viruses, bacteria, and protozoa are so small that we use much smaller measurements for them. They are even so small that we cannot use any sort of "stick" to measure them at all.

3. Move to the area set aside for your group to create models to compare the sizes of viruses, bacteria, and protozoa with the width of a human hair and a human red blood cell. The marked off area is 100 meters. It represents the width of a piece of hair. That would be the tiny space between your fingers where you held a piece of hair earlier. Select one of the microbes from the first column of the Microbe Reference Chart and draw what you think it might look like in the marked off area. See Figure 1. Decide how its size might compare to the width of a human hair.

4. Now go back to the Microbe Reference Chart and see what size the microbe you selected really is. Return to your drawing and make another drawing the proper size. How does it compare to your original?

5. Circulate among the drawings made by the other groups. Compare the microbe sizes and shapes. Are you surprised by the different sizes of microbes? How could you see these microbes? Did you create a good model of microbial size? Why do viruses, bacteria, and protozoa have such different shapes? How many bacteria do you think could fit into a teaspoon?

6. Why do scientists need to use models? Why can't they just look under a microscope to see what they need to see?

What Did You Find Out By Doing the Activity?

Before doing "Let's Get Small," did you know:

- anything about microscopes?
- anything about what bacteria do?
- whether or not you could see bacteria?
- if small organisms like bacteria vary in shape and size?
- if bacteria are useful to your life?

From this activity, did you discover:

- how you could find out the relative size of bacteria, viruses, and microbes?
- how models are used to study and compare small microbes?
- why scientists need models instead of visual drawings?
- some ways that you encounter microbes in your everyday life?
- ways that bacteria can be helpful or harmful?
- how viruses cause illness?

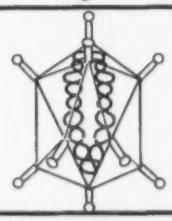
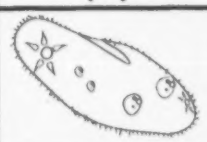
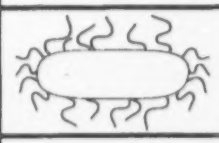
Organism	Effect on Body	Actual Size	Model Size	Shape not to scale
Poliovirus	Diseases of digestive tract, brain, and spinal cord	20 nm (0.02 µm) (0.00002 mm)	2 cm	
Adenovirus	Diseases of respiratory tract and digestive tract	90 nm (0.09 µm) (0.00009 mm)	9 cm	
Vaccina virus	Cowpox	200 nm (0.20 µm) (0.0002 mm)	20 cm	
Bacteriophage	Useful, transfers genes from one organism to another helping survival and biotechnology	60nm (0.06µm) (0.00006mm)	6 cm	
Paramecium	Common protozoa important in the food chain	200 µm (0.20 mm) (you can almost see it)	200 m (more than two football fields)	
Cilia of Paramecium	Leg-like hairs	200 nm wide (0.2 µm) (0.0002 mm)	20 cm	
Staphylococcus	Causes food poisoning	0.5 µm (0.0005 mm)	0.5 m	
Escherichia coli (E. coli)	Causes diseases and helps digestion	2.0 µm (0.002 mm)	2.0 m	
Human hair		0.1mm wide	100 m	
Human red blood cell	Carries oxygen in our bodies	10.0 µm (0.01 mm)	10 m	

Figure 1. Microbe Reference Chart.

THE YEAST OF OUR WORRIES

Have you ever been to a hospital? Did you notice the smell? Hospitals go to great lengths to create a germ-free environment. Can you think of some things that may prevent microbe growth?

Goal

To investigate strategies for reducing microbial growth.

Activity Time

60 minutes

Time to Get Ready

10 minutes

What You Need

Have the following for each team of 2 or 3:

3 clear cups or glasses
1 measuring teaspoon
1 thermometer (°C)
3 teaspoons of rapid-rise yeast
6 teaspoons of sugar
1 eye dropper
warm water (40°C)
1 roll of masking tape
1 spoon or stirring rod
1 pen or pencil
household products such as mouthwash, soap, detergent, hydrogen peroxide, cola, toothpaste
1 overhead projector or heating pad (optional)

Getting Ready

Be sure all the glasses are clean and oil-fee. Set up a glass of warm water, sugar, and yeast 20 to 30 minutes before you speak to the group. Show this to participants when you start your presentation.

Useful Information

Yeast are single-celled fungi. They reproduce by budding or producing spores, and can live in a variety of habitats. Yeast are found on plant leaves, flowers, and skin, and in soil, saltwater, and the intestines of warm-blooded animals. In some conditions, they multiply quickly. Other conditions prevent them from reproducing at all. Although some yeast are useful, other microbes are harmful. Consequently, we often try to rid areas of microbes. In hospitals, homes, and even on our skin, we use things to prevent the growth of microbes.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Allow participants, where possible, to touch and smell the household products for a better understanding of the variable. This will provide them with information that will allow the development of independent hypotheses and conclusions.
- Use small pieces of tape to mark the increase in the height of the layer of foam produced by the yeast solution introduced at the beginning of the activity.
- Construct a tactile diagram of "yeast budding.
- Mark glasses with the names and the test solutions used in braille or large print.

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- See the ***General Modifications*** for *Physically Impaired* listed in the **Introduction**, page V.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

For More Information

Brehm, M.A., et al. (1996). Determining differences in efficacy of two disinfectants using T-tests. *The American Biology Teacher, 58*(2), 111-113.
Finer, K.R. (1997). Evaluation of natural compounds for antimicrobial activity in the introductory microbiology laboratory. *The American Biology Teacher, 59*(1), 44-47.
Freeman, B.A. (1985). *Textbook of Microbiology.* Philadelphia, PA: W.B. Saunders Company.
Pelczar, M.J., Chan, E.C.S. & Krieg, N.R. (1993). *Microbiology: Concepts and Applications.* New York: McGraw Hill, Inc.
Rainis, K.G. & Russell, B.J. (1996). *Guide to Microlife.* Danbury, CT: Grolier Publishing.

How to Start the Activity

- Show participants pictures of yeast. Explain that they are living things. Discuss the things yeast might need to survive.
- Make sure that the participants have a basic understanding of the importance of including a control group in an experiment.
- Hold up the yeast, sugar, warm water solution that you set up earlier. Point out the layer of foam at the top. See Figure 1. Explain that in general, the more foam, the more yeast activity, and the more yeast activity, the more yeast. Demonstrate how to measure the height of the foam column.

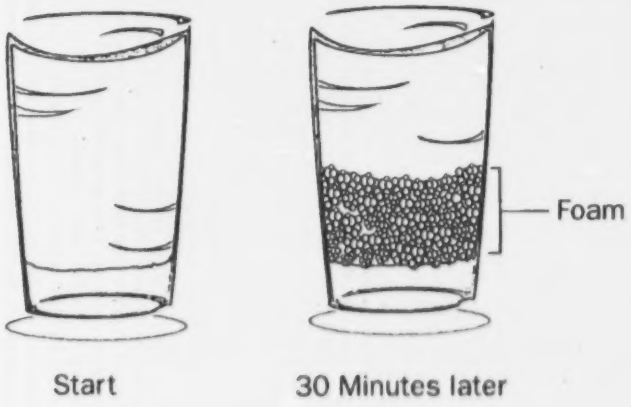


Figure 1. Setup of water, sugar, and yeast solution. After 30 minutes, a layer of foam appears above the solution.

- Explain that similar yeast activity occurs during bread baking and brewing. The honeycomb texture in bread is caused by the yeast activity.

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- If the yeast had been prevented from growing, what would have happened to the foam?
- What substances could you use to try to stop yeast growth?
- How would you design an experiment to stop yeast growth?

What the Data Mean

- In general, more foam indicates yeast activity, and more yeast activity indicates more yeast.

THE YEAST OF OUR WORRIES

Questions to Think About

Yeast are unicellular organisms. They reproduce through budding and spores. In some conditions, they multiply rapidly. Other conditions prevent them from reproducing at all. For this activity, we will use yeast as an example of a microorganism, and foam produced as a coarse measure of the activity and growth of yeast.

Safety Notes

- No running or playing with the lab equipment.
- If participants bring their own test materials, make sure they are not hazardous or illegal.
- Wash hands at the beginning and end of the activity.
- Yeast solutions may be flushed down a toilet at the conclusion of the activity.
- Do not put objects or hands in your mouth while conducting the activity.

What to Do

1. Select 2 of the household products to use as test solutions. Set your 3 glasses out on the table in front of you. Use masking tape to label one as control, and the other with the names of the test solutions you will use. Fill each glass 1/3 full of warm water (40°C). Add 2 teaspoons of sugar to each and stir to dissolve. Add 1 teaspoon of yeast to each glass and gently stir.

2. Add 5 drops of test solution to each of the numbered glasses. For the control glass, add 5 drops of water. Place them in a warm area of the room. The warmer it is, the faster the yeast will grow. An overhead projector or a heating pad works well for this purpose. See Figure 1.

3. Examine the glasses every 10 minutes for 30 minutes. Measure and record the height of the layer of foam. At 30 minutes, line up the glasses in order of foam height. Which substances were most effective in limiting the growth of yeast? Which substances did not limit the growth of yeast? How do you account for the differences in the amount of foam produced? Was your hypothesis correct? Construct a bar graph of your results.

4. What questions come from your results? To what other topics is this activity related? What did you learn from this activity? How does this activity relate to your life? What factors influence populations of microorganisms?

5. Do you think the substances killed all the yeast in the containers? How could you test to see if any yeast survived in the experimental group? Why do some yeast survive and some die? Why are differences in the yeast important for its survival as a species? What questions about yeast might be tested?

What Did You Find Out By Doing the Activity?

Before doing "The Yeast of Our Worries," did you know:

- that a lot of microbes are found in hospitals?
- how hospitals may try to eliminate harmful microbes?
- the effect that microbes have on other organisms, such as humans?

From this activity, did you discover:

- different methods used to prevent the growth of harmful microbes?
- how microbes reproduce?
- how the number of microbes on an object can be determined?
- if you can guarantee that the objects you come in contact with are microbe-free?
- any personal measures that you can take to reduce the number of microbes that may affect your health?

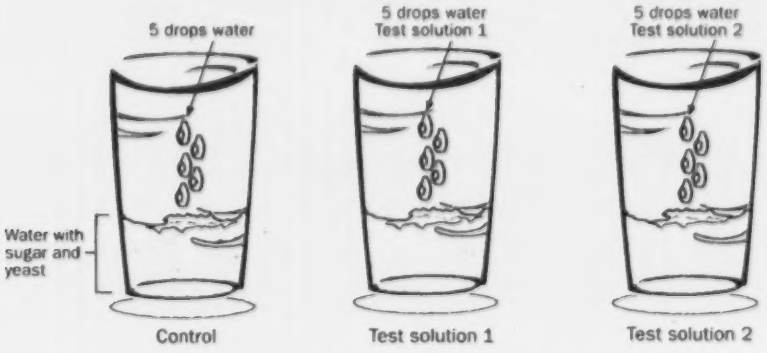


Figure 1. Possible student setup.

CABBAGE TODAY, SAUERKRAUT SOON

Do you think your food is bacteria-free? Well, think again! It isn't and it's a good thing! Without naturally occurring bacteria on cabbage, we wouldn't have foods like sauerkraut and kimchee to tingle our taste buds.

But cabbage doesn't just magically turn into sauerkraut in the fields. What conditions are required for the change to occur?

Goal

To demonstrate how bacteria naturally present on cabbage can change it into the common, fermented food called sauerkraut.

Activity Time

14 days

Time to Get Ready

30 minutes

What You Need

Have the following for each group of 3:

1 head of green cabbage (do not use pre-shredded)
1 sharp knife
3 teaspoons non-iodized table, kosher or pickling salt
1 1.5 to 2-quart bowl
1 plate that fits into the bowl
1 30 x 30-cm square of cheesecloth
1 zippered, plastic 1-gallon freezer bag
1 large spoon
variety of fermented foods such as sauerkraut, pickles, yogurt, kimchee
1 jar of commercially prepared sauerkraut (demonstration only)
1 vial pH paper or red cabbage pH indicator

Getting Ready

- The facilitator may choose to chop the cabbage for the participants prior to the meeting.
- The cabbage/salt mixture must be stirred daily and any scum must be skimmed off.
- If a pH meter or pH paper is not available, make pH indicator solution from red cabbage. Liquefy 2 cups of chopped red cabbage leaves and 1 cup of water in a food processor or blender. Strain through cheesecloth or a coffee filter. To use: add 10 drops of cabbage juice to 1 tablespoon of a sample to be tested. Or soak strips of white paper in the cabbage juice. Allow to dry, then dip paper strips into the sample to be tested. Color changes correspond to the following pH values shown in Figure 1.

Useful Information

Many foods are products of natural fermentation. Yogurt, cheese, and sauerkraut are just a few. Often a series of natural microbes breaks down complex compounds like sugar into simple substances like carbon dioxide and alcohol, and changes one food into another. Some bacteria produce acid in air-free environments as they grow. The acid and alcohol are toxic to food-spoiling microbes and can act as natural preservatives.

Different foods like cabbage, cucumbers, and grapes host different microbes. The microbes found naturally on cabbage produce a variety of acids and alcohols in air-free environments. Sauerkraut's flavor is the result of these chemicals. Salt draws water and sugars from the cabbage. The microbes use the sugars to make acids. With the right saltiness and temperature, the bacteria change the color, consistency, smell, and flavor of the cabbage. Sometimes these fermented foods are seasoned. For example, kimchee is fermented cabbage seasoned with garlic, red peppers, and ginger.

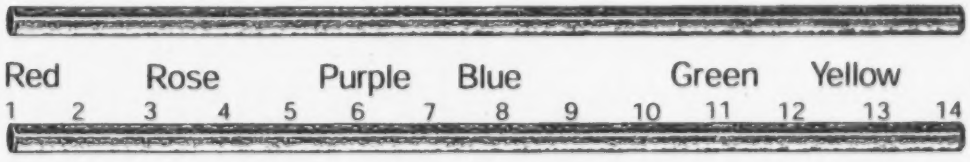


Figure 1. Color values that correspond to pH values for red cabbage indicator.

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Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Utilize the **Introducing the Activity** and the **Useful Information**. These sections contain well-defined questions and references for participants with visual impairments. Using the senses of smell, touch, and taste will allow the participant to understand the purpose of this activity.
- Follow the instructions recommended in the activity for group work. The steps and procedures are basic. This will allow the participant to follow voice instructions. Assign tasks where possible.
- Use a cheese grater in place of a knife if participants shred the cabbage.
- Provide detailed group discussions to develop an understanding of pH levels. Refer often to the color. Individuals who are blind have a good understanding of color and will appreciate the detailed observations. Have participants use descriptive terms, such as "fiery red" or "green grass."

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- Provide a cheese grater in place of a knife if participants will cut the cabbage. A larger and wider handle on the spoon may also be adapted.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

For More Information

Access Excellence. Teaching Ideas. Mixed-plate biology. Hawaiian style: kimchee fermentation. *http://www.gene.com/ae/atg/released/0275-JeanineNakakura/index.html*. This site is dedicated to teachers and provides lesson plans, resources, and an activities exchange for biology curriculum.

Brody, J.E. (1998). Adding cumin to the curry: A matter of life and death. *The New York Times, CXLVII*(51,085).

Burros, M. (1995). The virulent *E. coli* found in salami. *The New York Times, CXLIV*(49,952).

How to Start the Activity

Show the participants the sauerkraut and a head of cabbage. You might ask, "What if I told you these are the same thing?" Have the participants use their senses of smell and vision to identify how the sauerkraut and the cabbage are alike and different. Have them develop an explanation for why they are different. Guide their discussion to the presence of natural microbes on the cabbage and how under air-free conditions they change the cabbage into sauerkraut.

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- What product does the bacteria on cabbage produce during fermentation?
- What if you didn't shred the cabbage?
- What if you did not trim the damaged leaves from the cabbage?
- What if you used too much salt?
- What if you used another shredded vegetable instead of cabbage?

What the Data Mean

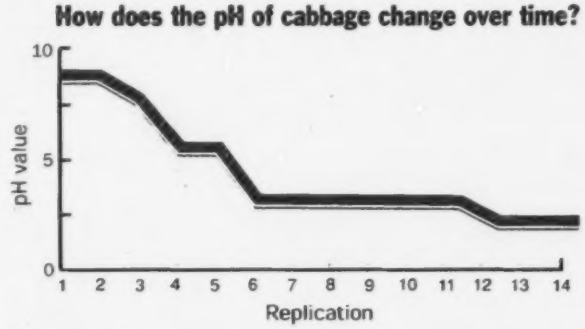
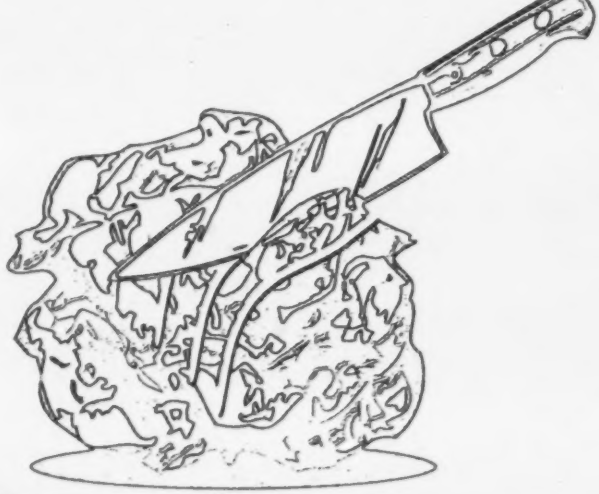


Figure 2. Change in pH during the incubation period. As the cabbage ferments, the pH decreases and then levels off.



CABBAGE TODAY, SAUERKRAUT SOON

Questions to Think About

Kimchee and pickles are just two of many fermented foods. How many others can you name? Can you describe them? How are they different? How are they similar? How are they made? What special environmental conditions are necessary to make them? How can you find answers to these questions?

Safety Notes

- Wash hands before and after touching the fermenting cabbage.
- Discard the sauerkraut at the end of the activity.
- Food, drinks, and gum are not allowed.
- Use the knife carefully when shredding the cabbage. Cut away from your body.
- Do not eat the cabbage/sauerkraut.

What to Do

1. Carefully examine the head of cabbage. Do you see any organisms on the leaves? Does that mean the leaves do not have organisms on them? Trim the cabbage head, removing any damaged leaves. Look again. Did you expose anything that looks like an organism?

2. Shred the cabbage and place it in a large bowl. Liberally sprinkle the cabbage surface with 3 teaspoons of salt. Compress the mixture slightly. Cover the cabbage with a clean plate. Weigh the plate down with a zippered, plastic 1-gallon freezer bag filled with water. Cover the bowl, plate, and freezer bag with cheesecloth to prevent insects from contaminating the mixture. Place in a warm, dry place. The temperature should be consistent at approximately 21°C (75°F).

3. Stir the cabbage/salt mixture each day. If the water has scum on top, skim it off. Observe changes in odor, color, texture, and pH on days 2, 7, and 14. Graph your results. Be sure the plate remains weighted to compress the cabbage and maintain as much of an air-free environment within the bowl as possible.

4. After you check the pH of the cabbage, taste one of the other fermented foods. How would you describe its taste? What is its pH? How does it compare with the pH of the cabbage?

5. What questions come from your results? To what other topics is this activity related? What did you learn from this activity? How does this activity relate to your life? What factors influence fermentation?

6. How can you learn more about fermentation? What factors could you manipulate to alter your results? What role did the salt play? Did the type of salt, such as pickling versus table salt, make a difference? What if you had used sugar, instead? What if you left the cabbage-salt mixture exposed to air?

7. Design a new experiment based on data you gathered or questions you asked during this investigation. Develop a hypothesis that can be tested in a controlled experiment that gathers quantitative data. Write a procedure in a numbered list to test your hypothesis. What is your control? What variables are important? How many trials have you included? What will you measure? How can you show your results in a graph?

What Did You Find Out By Doing the Activity?

Before doing "Cabbage Today, Sauerkraut Soon," did you know:

- why things taste sweet or sour?
- that sauerkraut is made from cabbage?
- that the same food can take many different forms?

From this activity, did you discover:

- that the same food item, such as apples, can take different forms (apple sauce, juice, cider, vinegar, etc.)?
- how sauerkraut is made from cabbage?
- how to find out what ingredients make sauerkraut taste different from cabbage?
- how to make sauerkraut at home?
- how to make other foods change form through fermentation?
- if the fermented foods you eat can grow mold?
- how refrigeration or some other method of preservation prevents mold from growing?

FUN WITH FOMITES

Fomites?! What are fomites? They are inanimate objects that can carry disease-causing organisms. Your cutting board, kitchen sink, and even that pen you keep putting in your mouth are all fomites. But can you do anything to affect the number of organisms on a fomite?

Goal

To investigate strategies for reducing bacteria on object surfaces.

Activity Time

2 45-minute sessions

Time to Get Ready

30 to 120 minutes

What You Need

Have the following for the entire group:

1 sink with running water
1 heat-proof container (optional)
1 stove or hot plate (optional)
1 set oven mitts/pot holders (optional)
1 laboratory refrigerator (optional)
1 set of Easy-Gel™ medium per group or 2.5 g nutrient agar

Have the following for each team of 3:

1 16-oz soft-drink bottle with screw cap
1 unopened box of cotton swabs
9 sterile nutrient petri plates
1 bar of soap
1 roll of paper towels
1 roll of cellophane tape
1 permanent marking pen
3 safety glasses
3 lab coats
disinfectants such as 70% alcohol solution, 10% bleach solution, liquid soap, Lysol®, hot water, household cleaners

Getting Ready

- Prepare disinfectant solution of 70% alcohol for each group by mixing 7 parts alcohol to 3 parts water in a large container. Subdivide the alcohol solution into smaller bottles. If using bleach as a disinfectant, mix 1 part bleach to 9 parts water in a large bucket, milk jug, or 2-L bottle. Subdivide this solution into 16-oz bottles.
- Be sure to use fresh, unopened boxes of cotton swabs for this activity. Commercial cotton swabs are sold sterile. Once the package is opened, microbes may find their way onto the swabs.
- Prepare petri plates as per the instructions on the Easy-Gel™ medium. Without lifting, slide the plates to a safe place where they will not be disturbed. Easy-Gel™ medium may be purchased from Microbiology Laboratories, L.L.C., 206 Lincoln Ave., Goshen, IN, 46526-3219, (219) 533-3351.
- If using another type of nutrient agar, follow the directions on the agar container. If none exist, add 2.5g nutrient agar to 97.5 mL warm water in a heat-proof container. Place on a hot plate. Stir constantly and bring to a boil. After liquid appears clear, pour approximately 10 mL of agar into each plate. Without lifting, slide the plates to a safe place where they will not be disturbed. Makes 10 plates.
- Two days before the group meets, make a sample plate. Swab a coin with all sides of a cotton swab. Open a petri plate and streak the surface with the end of the swab that touched the coin. Close the plate, label it, and tape it closed. Allow the plate to sit undisturbed at room temperature until the group meeting.
- Be sure to check on the participants' petri plates each day. Some plates look best after 24 hours, others after 48 hours. If microbial colonies are very heavy, place the plate in a plastic bag and store in a laboratory refrigerator until the second session. Remove the plates 30 minutes before the activity is to start.

Useful Information

It is hard to think of anything as sterile. That includes us. At birth, microbes immediately begin colonizing our bodies as they do every object in the world. They float around until they come in contact with a surface that provides food and shelter. Most are harmless, but some are pathogenic or disease-causing. For this reason, we want to control the number of microbes around us. The odds of becoming infected increase with the number of microbes on surrounding objects.

You are most likely to find microbes in and on dark, moist objects in contact with food, dirt, or vegetation. Bathrooms, hair brushes, refrigerators, kitchen sinks, and cutting boards often have lots of microbes. But door knobs and walls have few because they are nutrient-poor and dry. There are many ways to control microbe populations. Public sanitation and good hygiene control microbes before they enter our bodies. Vaccines and antibiotics control them once they enter our bodies.

In order to study microbes, they must be grown. This can be done several ways. One is to grow them on glass or plastic petri plates containing agar and a nutrient medium. Agar is a product made from algae. It solidifies the medium under certain conditions. A medium has the food, vitamins, and salts that help microbes grow. Each microbial cell reproduces to form a colony of millions of cells. We actually can see the colony with the naked eye. The individual cells are far too small to see without magnification. In natural environments, microbial colonies rarely form like those on a petri plate. The concentration and kinds of nutrients in nature are not suited to such extensive growth. The colony's shape, size, and color may indicate the organism that produced the colony.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Label petri plates 1 to 4 with braille or large print. Notches can be made with dabs of glue to number the plates.
- Refer to the sections **Introducing the Activity** and **Useful Information** for well-defined questions and references for participants with visual impairments.
- Focus group discussions on specific observations, such as those that relate to color, texture, size, and moisture. Individuals who are blind have a good understanding of color and will appreciate the detailed observations. Using our other senses for clarification with observations such as "Agar looks, feels and moves like Jell-O™."

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- See the ***General Modifications*** for *Physically Impaired* listed in the **Introduction**, page V.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

For More Information

AskERIC Lesson Plan: Bacteria. *http://ericir.syr.edu/Virtual/Lessons/Science/Biological/BIO0007.html*. This site is created as an online resource for Newton's Apple, a national science program. It provides lesson plans for teachers on various topics of biology.

Blair, B. & Bowen, W. (1996). Microbiology: It need not involve great expense & effort. *The American Biology Teacher, 58*(7), 418-419.

Germ free products. (September 9, 1997). *Japan now*, 3-4.

Glausiusz, J. (1997). The good bugs on our tongues. *Discover, 18*(10), 32-33.

Microwave your dishcloth to kill harmful germs. (October 15, 1997). *Times Community Newspapers*, 11.

Molasses recruits bacteria for cleanup. (1996). *Science News, 150*(19), 301.

Seppa, N. (1997). Salmonella plays the good-guy role. *Science News, 152*(20), 319.

Strauss, E. (1997). Mob action. *Science News, 152*(8), 124-125.

Winik, L.W. (February 8, 1998). Before the next epidemic strikes. *Parade Magazine*, 6-9.

How to Start the Activity

- Show a coin to the participants. Pass it among them. Ask them if they see anything on the coin and if it looks dirty. Show the participants the petri plate that you streaked from the coin. Explain that microbes collected from the coin multiplied in the plate to create the colonies they see now.
- Explain that a fomite is an inanimate object that can carry disease-causing organisms. Have the participants brainstorm about where fomites are in the room, i.e., sink, water fountain, table top, pens, pencils, keyboards.
- Have them rank the fomites from those likely to have the most to those likely to have the least microbe populations. Rank them again from those predicted to respond best to disinfecting to those predicted to respond least to disinfecting.

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- How could you show that objects other than a coin have microbes on them?
- If you clean an object, what do you think would happen to the number and kinds of microbes on it?
- What is the best way to clean things?
- How would you design an experiment to show that you have reduced the microbes on an object?

What the Data Mean

Generally, the successive streaks on the petri dish will have increasingly fewer bacterial colonies on them for both the clean and unclean surfaces. However, the streaks from the cleaned surfaces should show less bacterial growth.

FUN WITH FOMITES

Questions to Think About

We're always cleaning things and washing our hands. Usually, it doesn't even look like we're washing away anything. Why do we clean things? What types of things support the greatest amount of microbial growth? What is the best way to get rid of microbial growth? How can you find answers to these questions?

Safety Notes

- Food, drinks, and gum are not allowed.
- Wash hands before and after each session.
- Hair should be tied back to minimize contamination of sterile materials.
- If water containing microbes is spilled onto a person, wash with soap and water. If spilled onto equipment, swab with disinfectant and paper towels.
- DO NOT allow participants to collect microbes from their bodies. There is a small but present risk of collecting a microbe than can cause illness. Growing such a microbe in large numbers on a petri plate can be a risk.
- After microbes are placed on the petri plates, the plates MUST be taped shut. After the final session, kill all microbes on the petri plates by flooding each with bleach. Soak for an hour and place the plates in a plastic bag. Throw in the trash.
- When working with alcohol or bleach, use safety glasses and lab coats.
- When working with bleach or bleach solutions, BE CAREFUL not to spill it on yourself or clothing. Flush spills with liberal amounts of water.
- When in doubt about the presence of microbes, sterilize equipment by boiling for 20 minutes or by flooding with alcohol.

What to Do

Day 1 of the activity

1. Fomites are inanimate objects that can carry disease-causing organisms. Your cutting board, kitchen sink, and even your pen are all fomites. In this activity, you will look at microbes from fomites. Then you will check for microbes again after disinfecting the area. Wash your hands. Clean your work area by dabbing, not pouring, disinfectant solution onto a paper towel and swabbing your area.

2. Choose an object in the room and swab it with all sides of a cotton swab by turning and twisting the swab as you move it across the object's surface. See Figure 1. Swabbing a coin. Open the lid of a petri plate, and GENTLY make four streaks on the plate's surface as shown in Figure 2. Use firm, but GENTLE pressure and do not retrace your previous streaks. Your streaks should make only very slight impressions in the agar. Close the plate. Label it with the objects' name, your initials, and the numbers 1 to 4 next to each of the streaks in the order that they were made. Without covering the plate's surface, seal it with two pieces of tape.

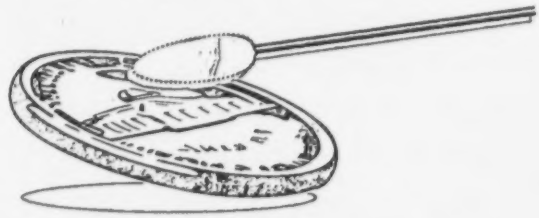


Figure 1. Swabbing a coin.

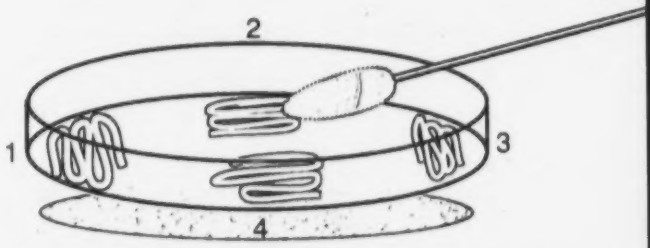


Figure 2. Streaking technique for petri plates. *Make 4 separate streaks.*

3. Clean half of the object you swabbed with water. Using the same process, re-swab the cleaned area for microbes. Open the lid of a new petri plate and GENTLY make 4 streaks on the plate's surface with the end of the swab that touched the object as you did previously. Close the plate. Label it with the object's name, control, your initials, and the numbers 1 to 4 in the order that the streaks were made. Seal the plate with tape.

4. Use one of the disinfectants to clean the other half of the object you swabbed. Using the same process, re-swab the area for microbes. Open the lid of a new petri plate, and GENTLY make 4 streaks on the plate's surface with the end of the swab that touched the object as you did previously. Close the plate. Label it with the object's name, the disinfectant you used, your initials, and the numbers 1 to 4 in the order that the streaks were made. Seal the plate with tape.

5. Soak the cotton swabs in disinfectant. Throw the cotton swabs in the trash at the end of the activity. Give the petri plates to your facilitator to incubate at room temperature until the next session. Clean your work area with disinfectant solution. Wash your hands.

Day 2 or 3 of the activity

6. Get your initial petri plate from your facilitator. Do not open it. What do you observe? Which streaks have more microbes? Do you see a pattern in the amount of microbes in each streak? At what point were there too few microbes to grow a colony on your plate?

7. Get your other petri plates from your facilitator. Do not open them. What do you observe? How do the streaks compare to those in your first plate? Construct a table that compares the plates from your group before and after cleaning the objects. Be sure to indicate whether microbes grew in each streak.

8. Return the petri plates to your facilitator. Clean your work area with disinfectant solution. Wash your hands.

9. Compare your results with those of other groups. What questions come from your results? To what other topics is this activity related? How does this activity relate to your life? How does cleaning influence the populations of microbes? Could your lab technique have affected your results?

10. How can you learn more about microbes? What factors could you change to alter microbial populations? Could you design an experiment to test a new hypothesis? What would you use for a control? What procedure would you use? How many variables would you include? How many trials would you include? Could you show your results on a graph?

What Did You Find Out By Doing the Activity?

Before doing "Fun with Fomites," did you know:

- how people get diseases?
- what microbes need to survive on surfaces?
- how microbes go from one object to another?
- any products that can be used to reduce or eliminate harmful microbes from surfaces?

From this activity, did you discover:

- how microbes can multiply?
- how diseases can be caused by harmful microbes on surfaces?
- how effective products are at disinfecting?
- what happens if harmful microbes become resistant to disinfectants?
- some objects in your house that could be choice surfaces for harmful microbes?
- how to reduce the number of harmful microbes?

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PUDDLES

The last time you saw a puddle of water on the sidewalk, did you realize it was teeming with life? Bacteria, algae, fungi, and even tiny insects and crustaceans make their homes in puddles and other temporary bodies of water.

Goal

To discover the abundance and diversity of microbial communities in puddles.

Activity Time

60 minutes

Time to Get Ready

120 minutes over a 3-week period

What You Need

Have the following for each team of 3:

1 vial of pH paper or pH indicator
1 eye dropper
1 magnifying glass
1 microscope (optional)
3 glass slides and 3 cover slips (optional)
1 graduated cylinder or baby food jar marked in 1-milliliter increments
brown, green, and yellow paint color charts
4 artificial puddles
1 measuring teaspoon
distilled water
organic carbon sources such as potato flakes; sugar; fallen leaves; dry, fresh-cut grass

Getting Ready

Three weeks before

- Gather empty tennis ball cans, 1- or 2-L soda bottles with the tops cut off, plastic peanut butter jars, or quart-sized canning jars for the lab.
- Create an artificial puddle for each group in 2-L containers as shown in Figure 1. Fill each with distilled water. Add a handful of soil and some partially decayed leaves, grass, or hay. Label each container with the date. Store in a warm, well-lit location.

Two weeks before

- Create a second artificial puddle for each group.

One week before

- Create a third artificial puddle for each group.
- Locate a puddle or create one outdoors several days before the first meeting. If possible, use puddles in different locations or with different physical characteristics.

The day of the activity

- Create a fourth artificial puddle for each group.
- If a pH meter or pH paper is not available, make a pH indicator solution from red cabbage. Liquefy 2 cups of chopped red cabbage leaves and 1 cup of water in a food processor or blender. Strain through cheesecloth or a coffee filter. To use, add 10 drops of cabbage juice to 1 tablespoon of a sample of water to be tested. Color changes correspond to the following pH values as shown in Figure 1 on the **Participant Page**.

Observation	Probable community
Gold or brown mat on bottom	Diatoms
Dark green mat with bluish coat	Cyanobacteria
Thin grass green threads	Green algae
Green spherical net of threads	Green algae
Uniformly green water	Green algae
Pink water (particularly in bird baths)	Flagellated algae
Slimy, colorless patches on bottom	Protozoans

Table 1. Puddle organisms.

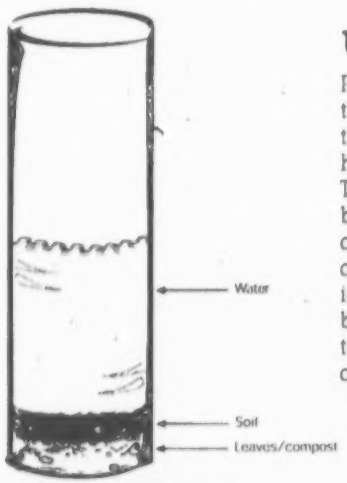

Figure 1. Puddle setup.

Useful Information

Puddles are often teeming with life. The types of organisms present depend on many things. Size, sun, temperature, and food all help determine what can live in a puddle. Thirty to 80 different kinds of protozoans, bacteria, algae, and fungi may be found in one puddle. The numbers and types of organisms change continually. Some can be identified with microscopes. Others, like bacteria, require special equipment and tests. A few can be identified by closely observing the puddle. See Table 1.

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Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Emphasize the discussions that are outlined in **Useful Information** and **Introducing the Activity**. They will be very beneficial to the participant for comprehension of the material and purpose.
- Emphasize that group discussions should include specific and detailed observations that use terms such as "fiery red" or "green grass." When discussing pH levels, refer often to the colors. Individuals who are blind have a good understanding of color and will appreciate the detailed observations.
- Construct tactile diagrams of organisms found in the puddles. Include detailed descriptions of each organism.

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

- Locate puddles outside in accessible areas.
- Show slides of the microscopic view of organisms if the participant cannot comfortably work at the microscope station. A magnifying glass is also an excellent adaptation.

Physically Impaired

- Wrap an elastic band around the jar to provide the participant better grasp. The larger the mouth is on the jar, the easier it will be to manipulate and transfer material into it.
- Show slides of microscopic views of the organisms if the microscope station is not comfortable for the participant. A magnifying glass is also an excellent adaptation.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

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Palmer, S. & Cairns, J. *Microbes in the World Around Us: A Laboratory Guide for the Study of Microbes in Environmental Samples* (Unpublished manuscript). MINTS. Virginia Tech Museum of Natural History, Virginia Tech, Blacksburg, VA.

How to Start the Activity

Take the group to an outdoor puddle. Have them list the features of the puddle. How did the water get there? Why is it still there? What lives in a puddle? What evidence of living things do they see? How many different kinds of living things do they think can be found in this puddle? What limits the variety or number of organisms found in a puddle? How will this puddle change over time? Is this puddle different from others? What factors affect living things or communities in puddles? What could they do to learn more about puddle organisms and how puddles change over time?

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- What might affect the growth of microorganisms in our artificial puddles?
- What do plant-like microorganisms need to live?
- What might bacteria feed on in natural environments?
- What are some sources of carbon that we can provide for bacteria?
- How do microorganisms get into puddles?

What the Data Mean

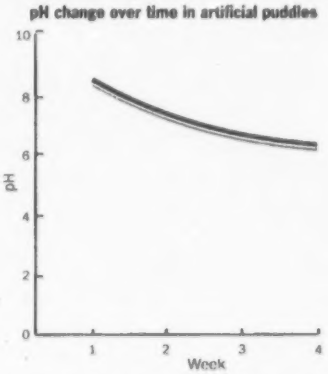

Figure 2. Graph of pH of artificial puddles over 3 weeks. pH decreased, possibly due to microbial activity. As microbes respire, they release carbon dioxide that reacts with water to form carbonic acid, lowering pH. Acidic waste products from microbial decay may also build up from decaying vegetation.

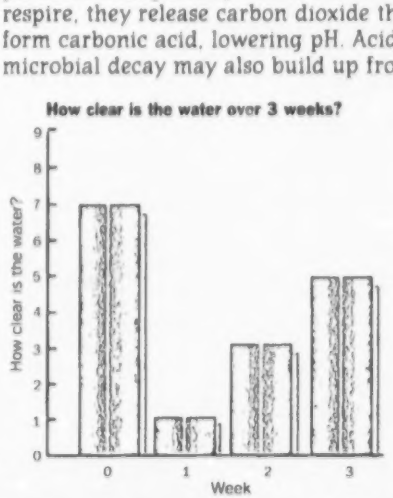

Figure 3. Graph of turbidity or clearness in artificial puddles over 3 weeks. Turbidity was high after adding soil. As material settled, turbidity decreased in Week 1. As microorganisms grew and reproduced, turbidity increased.

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PUDDLES

PARTICIPANT

Questions to Think About

Is there life in puddles? We have all splashed through puddles after rainy days. Some are temporary and last only a few hours while others last much longer. Does anything live in these puddles? If so, what? What environmental factors might affect what kind or how many organisms can live in a puddle? How do puddles change over time? How do organisms colonize, or end up in puddles? How can you design artificial puddles to answer these questions?

Safety Notes

- Food, drinks, and gum are not allowed.
- Wash hands at the completion of the activity.
- Avoid touching your mouth or eyes after handling water from puddles.

What to Do

1. Study your artificial puddles. Line them up according to the dates they were created. How are they similar to the puddle you observed outdoors? How are they different?

2. Use the paint color chart to record the colors of each artificial puddle. Record the color at the bottom as well as the middle of each water column. What do the colors suggest about the number or variety of organisms in the puddles? Can you determine what causes the colors on the bottom? Did the puddles' colors change over time?

3. Use pH paper or the red cabbage indicator to determine the pH of each puddle. See Figure 1 for red cabbage pH indicator colors. Graph your results. What might affect the pH in a puddle?

4. Collect a sample of water from the middle of each artificial puddle. If the sample is very turbid, or cloudy, do serial dilutions until the water appears clear. The number of times the solution needs to be diluted before it appears clear is your measure of turbidity. Use a graduated cylinder or baby food jar. Remove 1 part water from the puddle and add 1 part distilled water and shake to mix. If the solution is still cloudy pour off half and add another 1 part distilled water. Repeat until the solution is clear. If the sample requires 3 dilutions before it becomes clear, record a "3" as a measure of turbidity. Graph your results. What factors might cause the water to appear cloudy? Did the puddles' turbidity change over time? Graph your results.

5. Use an eye dropper to remove a sample of water from each puddle. If a microscope is available, place a drop of water on a slide and count the number of organisms and/or different kinds of organisms in the field of view at low power. Figure 2 shows some organisms that you may see. If no microscope is available, count the number of larger organisms you observe in a sample of known volume. Put this sample in the bottom of a baby food jar or a dish for closer examination. Be sure to examine and sample different parts of each puddle–the surface, middle, and bottom of the water column. Did the populations change over time? What factors caused these changes? If available, use keys and field guides to identify the organisms. If you do not have keys, sketch each kind of organism and make your own classification guide.

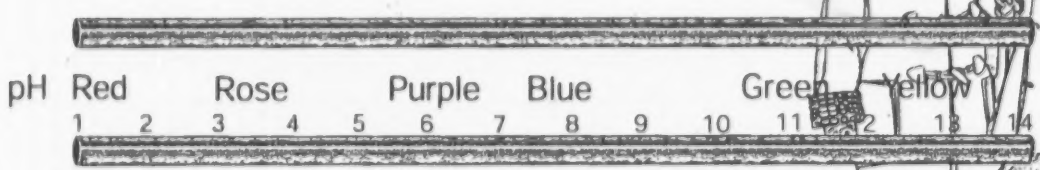

Figure 1. Red cabbage pH indicator colors.

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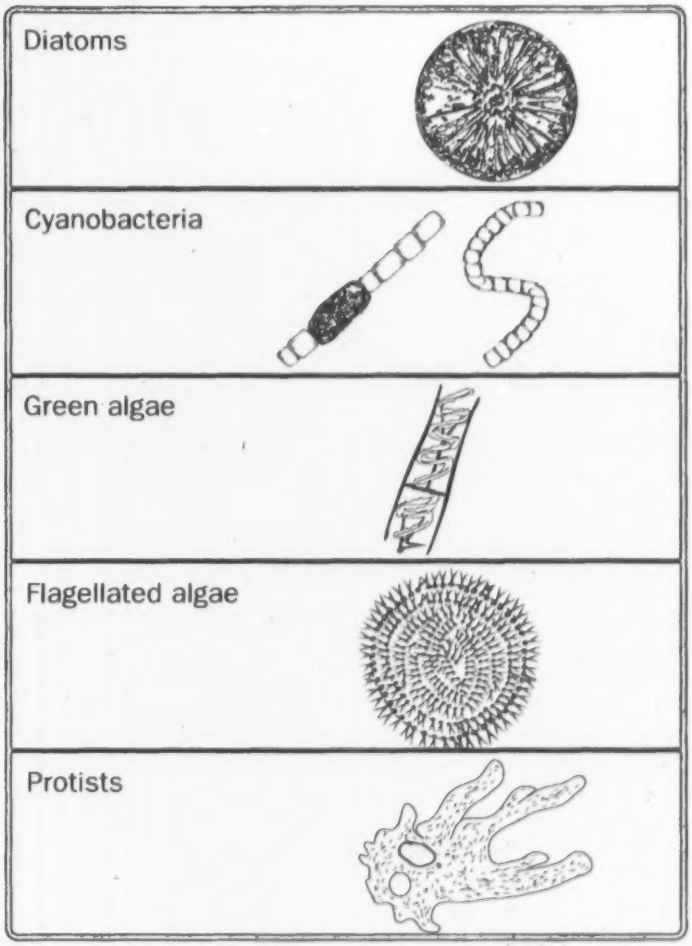

Figure 2. Sketches of common organisms found in puddles.

6. What questions come from your results? To what other topics is this activity related? What did you learn from this activity? How does this activity relate to your life? What factors influence the populations of microorganisms?

7. How can you learn more about puddles? How can you learn more about what affects the populations of microorganisms in them? Could you study puddles outdoors? What factors could you manipulate to alter microbial populations? What factors might favor the growth of bacteria? of algae? of protozoans? Could you design an experiment to test a new hypothesis? What procedure would you use? What would you use for a control? What variables are important? How many trials would you include? What will you measure? Could you show your results in a graph?

What Did You Find Out By Doing the Activity?

Before doing "Puddles," did you know:

- what can be found in puddles besides water?
- how water gets into puddles?
- how puddles can support life?

From this activity, did you discover:

- what different types of living organisms exist in puddles?
- what factors affect an organisms survival in puddles?
- how the living organisms in puddles can be identified?
- if the living organisms in different puddles vary?
- how living organisms in the same puddle can change over time?
- how you could create a community of living organisms in a puddle?
- what products you use that could reach living organisms in puddles and alter their ability to survive?

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YEAST ON THE RISE

All breads are not created equal. Why are some flat and others fluffy? What is the difference between tortillas and sandwich bread? Are all breads made of the same ingredients? What happens if you change the ingredients in bread dough?

Goal

To investigate variables that affect the energy and carbon dioxide production of yeast in bread dough.

Activity Time

60 minutes

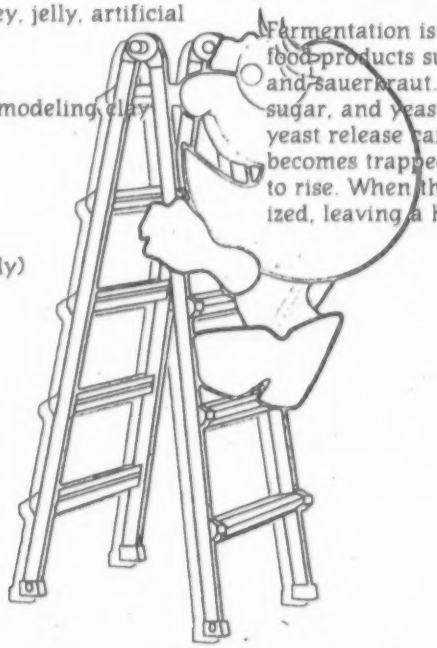
Time to Get Ready

15 minutes

What You Need

Have the following for each team of 3:

2 cups of flour
3 paper or plastic cups
2 packages of rapid-rise yeast
2 cups of warm water
6 teaspoons of sugar
alternate sweeteners such as honey, jelly, artificial sweeteners
24 clear straws
24 clothespins or 9-inch piece of modeling clay
1 measuring teaspoon
1 tray or cookie sheet
1 metric ruler
1 permanent marking pen
1 loaf of bread (demonstration only)



Getting Ready

- Mix 1 cup of flour, 2 teaspoons of sugar, and 1/3 package of yeast. Very slowly add warm water a tablespoon at a time and knead the mixture to produce a stiff dough. The dough should not stick to your hands or work surface. If it is too sticky, add more flour.
- If using a bulk supply of yeast, measure out 1 teaspoon per group.
- Measure a second cup of flour, 1 cup of warm water (40 to 45°C), and 6 teaspoons of sugar into paper or plastic cups for each group.
- If clothespins are not available, modeling clay can be used to hold the straws upright. Make half-inch balls of clay for each straw. Push the end of the straw into the clay. Push the clay down on the table to flatten the bottom side.
- Mark straws at 3-cm intervals ahead of time (optional).

Useful Information

Yeast are living organisms that require food, water, and a warm place to grow. They break down sugars as a food source for their energy needs and produce carbon dioxide gas and ethanol as waste products. This process is called fermentation.

Fermentation is important in the production of many food products such as bread, yogurt, cheese, pickles, and sauerkraut. When flour is mixed with water, sugar, and yeast, the yeast feed on the sugar. As the yeast release carbon dioxide and alcohol, the gas becomes trapped as bubbles in the dough, causing it to rise. When the bread is baked, the gas is vaporized, leaving a honeycomb texture.

Suggestions to Modify the Activity for Those Who Are Exceptional

Specific modifications for this activity are found here. For common considerations when modifying activities for exceptional participants, see page V of the **Introduction**.

Blind or Visually Impaired

- Allow the participants to touch and smell different types of bread. Discuss the distinct characteristics of bread, such as texture and density. Allow participants to taste the different sweeteners. Sensory stimulation is beneficial to participants, as it helps achieve a better understanding of the activity.
- Have the participants mark the 3-cm intervals on the straws with small pieces of tape. This will benefit the participants if they do not have access to a braille ruler. Mark the final measurement of the dough in the straw with tape also.

Deaf or Hard-of-Hearing

- See the ***General Modifications*** for *Blind or Visually Impaired* listed in the **Introduction**, page V.

Mobility Impaired

- See the ***General Modifications*** for *Mobility Impaired* listed in the **Introduction**, page V.

Physically Impaired

- Attach a ruler to lengthen instruments with short handles to make them easier to manipulate.
- Wrap an elastic band around the measuring devices to provide the participant with a better grasp.

Cognitively Impaired

- See the ***General Modifications*** for *Cognitively Impaired* listed in the **Introduction**, page V.

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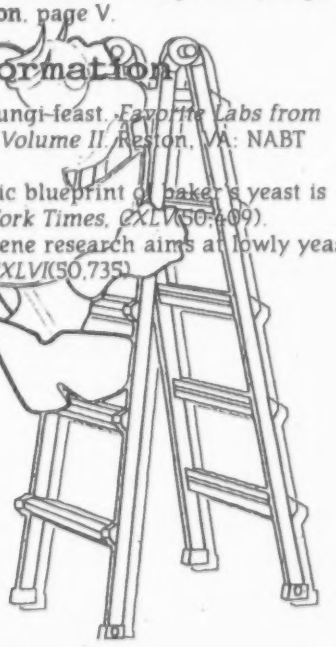

How to Start the Activity

- Show the participants the dough mixture prepared earlier and a loaf of bread. Have them discuss the similarities and differences between the two.
- Impress upon the participants that yeast are living organisms with needs similar to other living things. Discuss the needs of living things.
- Explain that yeast, like humans, make waste products. Yeast and humans produce waste carbon dioxide.

Let's Make a Hypothesis

Discuss the following questions to help guide the participants to make hypotheses.

- What do the bread and dough have in common?
- What makes bread rise?
- What is the living component in bread?
- What feeds the living component in bread?
- What makes sandwich bread different from flat breads such as matzoh, tortillas, or taco shells?

What the Data Mean

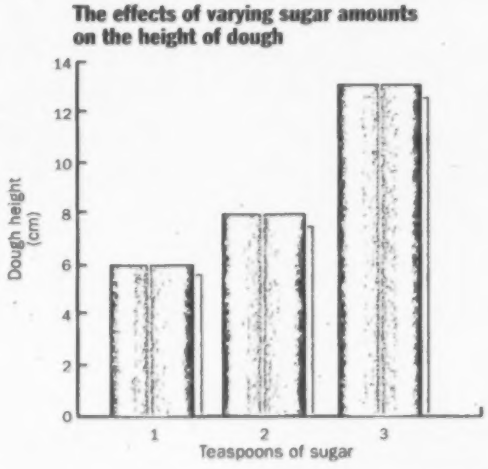

Figure 1. Graph of the effects of different sugar amounts on the height of dough. Increasing the amount of sugar increases the production of carbon dioxide, which in turn increases the height of the dough in the straw.

YEAST ON THE RISE

Questions to Think About

Bread is one of the most basic foods in our diet. How many different kinds can you name? What makes them different? How are they similar? What ingredients are needed to make bread? What role does each ingredient play? What makes dough rise? Yeast are living organisms. What do they eat? At what temperature do they live best? How can you find answers to these questions?

Safety Notes

- Wash hands before and after the activity.
- Do not eat the dough.
- Food, drinks, and gum are not allowed.

What to Do

1. Consider the bread ingredients before you begin. Which one makes the bread rise? What limits the bread's ability to rise?

2. Dust your tray and hands with flour. Divide your portion of flour into 4 equal mounds of 1/4 cup each. Designate the mounds as Control 1, 2, and 3. Measure 1 teaspoon of sugar and add it to Mound 1. Measure 2 teaspoons of sugar and add to Mound 2. Measure 3 teaspoons of sugar and add to Mound 3. Add no sugar to the Control Mound. Pour 1/4 package, or 1/4 teaspoon, of yeast over each mound. See Figure 1. While continuing to keep each mound separate, very slowly add warm water a teaspoon at a time to moisten the mixtures. Continue to add water and knead by hand until the mounds have doughy consistencies. The dough should not stick to the tray or your hands. If it is too sticky, add more flour. Form each mound into a ball. See Figure 2.

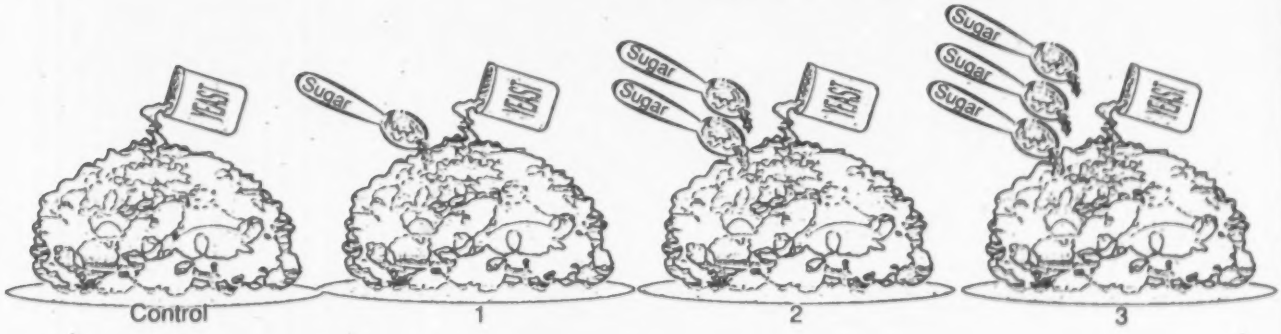

Figure 1. How to set up the flour, yeast, and sugar.

Figure 2. Add water and form into 4 balls of dough.

3. Measure 3 cm from the end of a straw and mark it. Repeat the process with 11 more straws.

4. Working quickly, push 3 straws into the Control Mound, filling each with dough to the 3-cm mark. Label the straws as Control. Repeat the process for Mounds 1, 2, and 3 and label accordingly. See Figure 3.

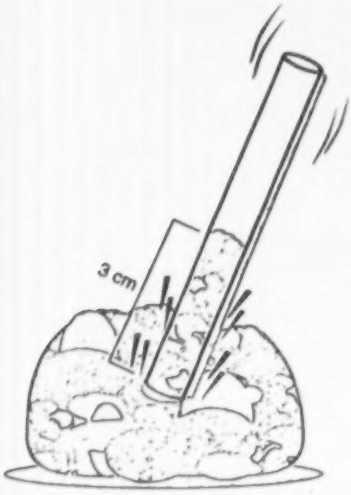

Figure 3. How to use a straw to remove dough from the dough ball.

5. Remove the straws from the dough and pinch the ends of the straws to push the dough away from the ends. Place a clothespin perpendicular to the dough end of each straw. The clothespins should function as stands, holding the straws upright. Mark the new height of the dough on each straw. See Figure 4.

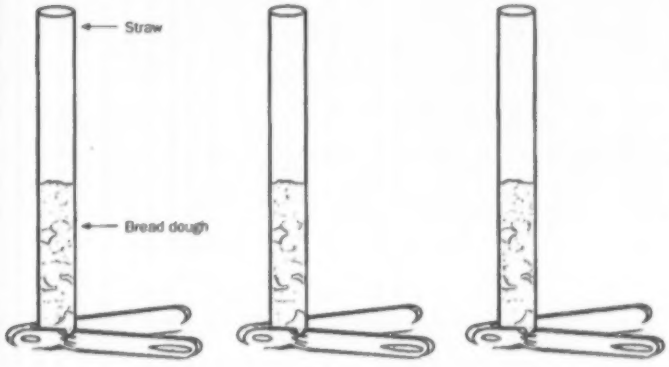

Figure 4. Clothespin straw holder assembly.

6. What is the variable or factor that changes in this activity? Why did you create 3 straws from each mound? Which dough will rise the most? As the dough begins to rise, it will push up into the straws. Predict how far the dough will rise in each straw in 10, 20, and 30 minutes. Write down your predictions.

7. After 10 minutes, measure and mark the heights of the dough in the straws. Calculate an average height for each mound. Repeat the process after 20 and 30 minutes. Graph your results.

8. While you are waiting for the dough to rise in your straws, repeat the procedure. This time instead of using sugar, use other sweeteners. Measure and mark the heights of the dough in the straws. Graph your results. Are they similar to the results you got using sugar?

9. What other questions come from your results? To what other topics is this activity related? How does this activity relate to your life? What did your graph show?

10. How can you learn more about the metabolic activity of yeast? What procedures would you use? What would you measure? What if you changed the kind of flour? What if you left some ingredients out? Design an experiment with one independent variable, a control, and at least three replicates per treatment group.

11. Design a new experiment based on data you gathered or questions you asked during this investigation. Develop a hypothesis that can be tested in a controlled experiment that gathers quantitative data. Write a procedure in a numbered list to test your hypothesis. What is your control? What variables are important? How many trials have you included? What will you measure? How can you show your results in a graph?

What Did You Find Out By Doing the Activity?

Before doing "Yeast on the Rise," did you know:

- how bread is made?
- why you use yeast to make bread?
- why bread has bubbles in it?

From this activity, did you discover:

- the factors that affect how quickly yeast grow?
- how yeast produce the bubbles you see in baked bread?
- how the different ingredients in bread affect the growth of yeast?
- if breads that contain more sugar have a more bubbly texture than those that don't contain as much sugar?

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